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Hon. W. J. ASSELSTINE, *Minister* JOHN F. WALKER, *Deputy Minister*

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Tungsten Deposits of British Columbia

by

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THE GOVERNMENT OF
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CORRIGENDUM

Page	35,	paragraph 4	- Mona Nickel should read Mond Nickel.
"	41,	" 1-2-4	- grandiorite should read granodiorite.
"	77,	" 2	- Latitude north 48 degrees should read latitude north 49 degrees and longitude west 125 degrees should read longitude west 121 degrees.
"	93,	last paragraph	- latitude north 43 degrees should read latitude north 49 degrees.
"	94,	" "	- longitude west 117 degrees 6 feet should read 117 degrees 6 minutes.

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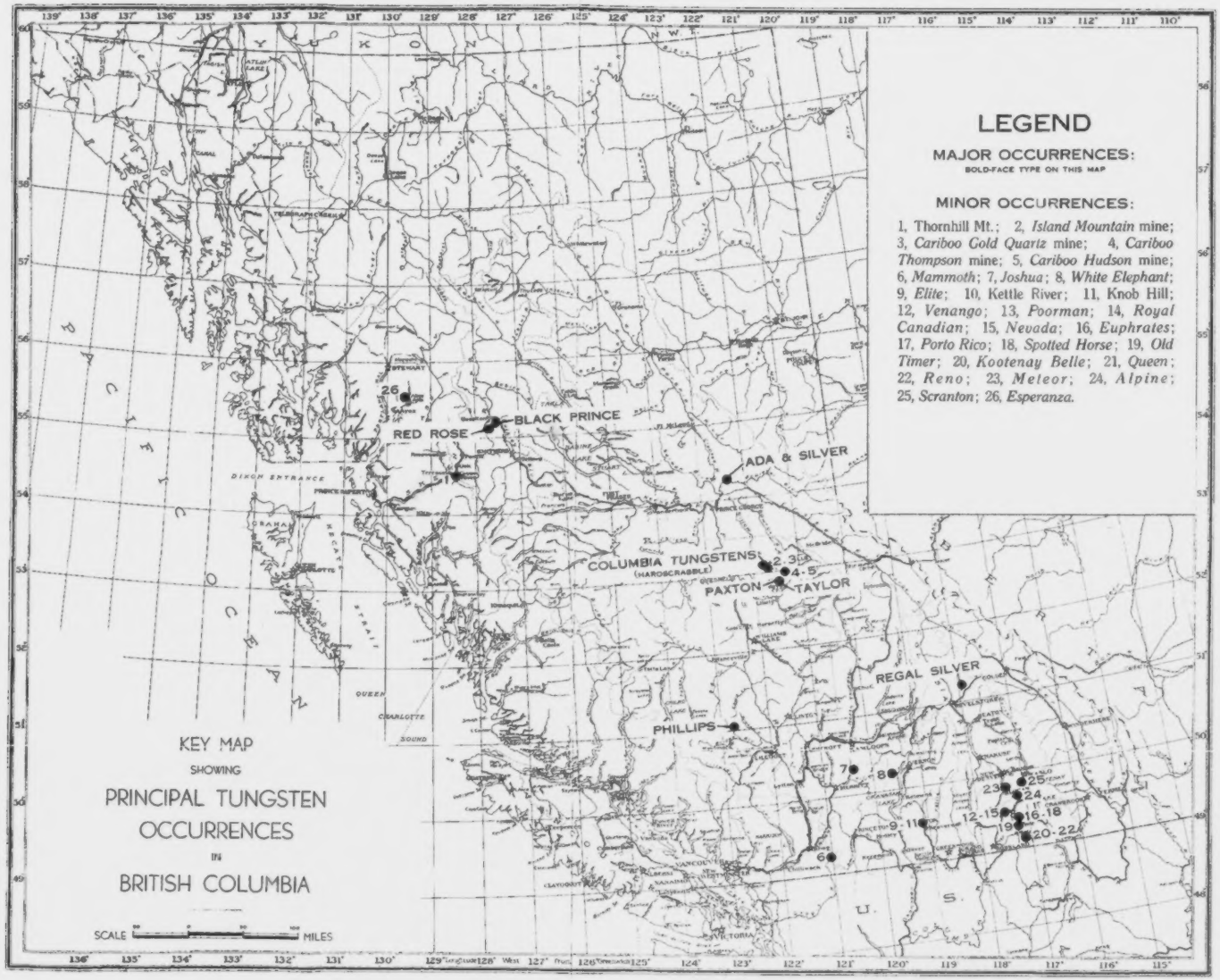
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U. S.

Key map showing principal tungsten occurrences in British Columbia.

PREFACE

This bulletin describes all the more important tungsten deposits in British Columbia and most, though not all, occurrences that are of mineralogical interest only. With the exception of the Ada and Silver, reported upon in 1935 by Douglas Lay of the British Columbia Department of Mines (VII, 1935, pp. C 30 - C 32), the important properties were examined by the writer during the field seasons of 1939 and 1940.

To make the bulletin more comprehensive, the chapter on the description of properties is preceded by a chapter on tungsten and another on its general world distribution.

The purpose of the bulletin, insofar as its size permits, is twofold; to supply prospectors with information that will aid them in the search within the Province for tungsten, a metal that can be generally mined profitably at the present time; and to supply interested people with information concerning the known tungsten deposits.

The writer wishes to acknowledge the kind assistance and cooperation rendered by mine officials and prospectors associated with the properties visited. During the examination of the Regal, the writer was accompanied by Stuart S. Holland, a member of the British Columbia Department of Mines staff. Charles B. Newmarch, the writer's student assistant during the 1940 field season, greatly facilitated the field work by his capable and hearty cooperation.

A bibliography of the references cited may be found at the end of the report. This bibliography has been classified according to subject matter into seven groups of titles. Reference in the text to a title is made by preceding the name of the author or year of publication by the subject group-number of the title. Thus (VII, Cairnes, 1920) or ". . . . . Cairnes (VII, 1920) indicates that the reference may be found in group VII under the name of Cairnes for the year 1920.

CHAPTER I

INTRODUCTION.

GENERAL DISCUSSION OF TUNGSTEN.

Tungsten is a metal that possesses many exceptional properties. Its melting point of 3000° C is considered to be higher than that of any other metal; its specific gravity of 19.3 to 21.4 is 70 per cent greater than that of lead, and it is particularly resistant to chemical agents (I, Mellor, p. 572). It is very ductile and possesses sufficient strength, hot and cold, to be used as incandescent filaments ranging in diameter from 0.060 to 0.0005 of an inch (III, Sykes, 1935, p. 376). Because of these many desirable properties, tungsten is becoming more and more used in industry with every new advance in metal technology.

TUNGSTEN MINERALS.

Literature mentions thirteen tungsten minerals, but of these only four, scheelite, ferberite, wolframite and huebnerite, are of commercial importance. Table I lists all the tungsten minerals giving their composition. The physical properties of the four more important are given in the paragraphs that follow Table I.

TABLE I. Tungsten minerals

Mineral	Composition	Tungstic Oxide, (WO_3) per cent.
Scheelite	Calcium tungstate ($CaWO_4$)	80.6
Ferberite	Iron tungstate ($FeWO_4$), theoretical iron end-member of wolframite series	75.3
Wolframite	Iron-manganese tungstate (Fe, Mn, WO_4), variable iron and manganese	75.3
Huebnerite	Manganese tungstate ($MnWO_4$) theoretical manganese end- member of wolframite series	75.3

(cont'd)

TABLE I (cont'd)

Mineral	Composition	Tungstic Oxide, (WO_3) per cent.
Powellite	Calcium molybdate with up to 10 per cent. WO_3	
Chillagite	Lead tungstate-lead molybdate (3 $PbWO_4PbMoO_4$).	21.7
Stolzite	Lead tungstate ($PbWO_4$) tetragonal crystals	51.0
Raspite	Lead tungstate ($PbWO_4$) monoclinic crystals	51.0
Cuprotungstite	Hydrous copper tungstate ($Cu_2WO_5.H_2O$) (Schaller, 1932, p. 236)	56.7
Cuproscheelite	Impure mixtures of cuprotungstite and scheelite (Schaller, 1932, p. 236)	
Tungstenite	Tungsten sulphide (WS_2)	94.0
Tungstite	Hydrous tungstic oxide ($WO_3.H_2O$)	92.8
Ferritungstite	Hydrous ferric tungstate ($Fe_2O_3.WO_3.6H_2O$)	52.2

Scheelite. Lustre, greasy adamantine. Colour, white, buff, yellowish through brownish to reddish. Streak, white. Hardness, 4.5. Fracture, uneven. Brittle. Specific gravity, 5.9 to 6.2. Granular, compact.

Ferberite. (Reinite in Dana) Lustre, submetallic to metallic. Colour, black. Streak, dark brown to nearly black. Hardness, 5. Cleavage, one perfect. Fracture uneven. Brittle, Specific gravity, 7.5.

Wolframite. Lustre, submetallic. Colour, dark greyish or brownish black. Streak, nearly black. Hardness, 5 to 5.5. Cleavage, one perfect. Fracture, uneven, brittle. Specific Gravity, 7.2 to 7.5. Crystalline, often bladed, granular.

Huebnerite. Lustre, submetallic to adamantine. colour, brownish red to brown to nearly black. Streak, yellowish brown, greenish grey. Hardness, 5. Cleavage, one perfect. Fracture, uneven, brittle. Specific gravity, 7.2 to 7.3. Usually in bladed form.

The minerals ferberite, wolframite and huebnerite form a continuous chemical series of minerals between the limits of pure iron tungstate (ferberite) and pure manganese tungstate (huebnerite). Ferberite, the iron tungstate, is arbitrarily considered to have less than 20 per cent. Manganese tungstate, and huebnerite, the manganese tungstate, to have less than 20 per cent. Iron tungstate (I. Hess, 1917, pp. 21-29). Wolframite is any iron-manganese tungstate with an iron and manganese content between the above limits. A chemical analysis is usually necessary to distinguish between the three minerals of the wolframite series. However, lacking specific chemical analyses, such minerals may be provisionally referred to as wolframites.

FIELD TESTS FOR TUNGSTEN MINERALS.

Field chemical-tests should be made whenever possible to check any preliminary identification of a tungsten-bearing mineral, previously made either on the basis of its physical properties, or its fluorescence in ultra-violet light. Scheelite from a new find should always be checked chemically. The necessary apparatus for these tests is simple and the procedure rapid and decisive. The details of the tests will be given in the following paragraphs:

The presence of tungsten in a mineral is checked by two main methods depending on whether or not the mineral is attacked in dilute hydrochloric (muriatic) acid. If attacked in dilute acid, the simple acid test may be used, if not, the fusion test must be used. Of the main tungsten-bearing minerals, scheelite is attacked in acid but the wolframites are relatively insoluble and must be fused.

The proper method may be preliminarily determined merely by noting the colour of the mineral; scheelite ranges from white to orange, whereas the wolframites are almost invariably dark brown or black.

Simple acid test: For this test all that is required is some hydrochloric (muriatic) acid, a test-tube or any small glass or porcelain vessel that will not be attacked by acid; and a small amount of zinc or tin in the form of

shot or sheets that can be cut into thin pieces.

The mineral to be tested is pulverized to a fine powder and boiled in the acid for a few minutes. If the mineral is a soluble tungsten compound such as scheelite, a yellow powder, tungstic oxide (WO_3), will separate from the solution. To confirm this separation, a few pieces of zinc or tin, or even solder are added to the solution which is boiled gently for a minute or two and, if tungstic oxide has been separated, the solution will turn indigo-blue. This blue colour probably results from the partial reduction of the tungstic oxide (WO_3) to a tungsten oxide, (W_2O_5) (1, McAlpine and Soule, 1933, p. 290) by the nascent hydrogen liberated from the hydrochloric acid by the action of the zinc or tin. The test with zinc or tin is a very delicate one for a soluble or partly soluble tungsten-bearing mineral and is, of course, a splendid test for scheelite.

Fusion test: This test is used for more refractory minerals, such as the wolframites.

The materials required for the test are: sodium carbonate or bicarbonate (ordinary kitchen baking-soda); a fine platinum or steel wire, 2-4 inches long with a loop, about 1/16 -inch diameter at one end made by bending the end of the wire around a needle or pencil-point; an open flame such as a candle, or alcohol lamp; a small blow-pipe; a test-tube or other small acid-resisting vessel such as a glass tumbler or a cup; hydrochloric (muriatic) acid; and zinc or tin metal in small pieces.

The procedure for the fusion test is as follows: Make a soda bead with the platinum or iron loop by dipping the loop into a paste of soda and water, sintering this for a minute or two in a flame and then fusing it before a blow-pipe or in an otherwise very hot flame or hot coals; crush the unknown mineral to a fine powder. Take some of this powder, in quantity about the size of a pin-head, and mix with 5 to 6 volumes of soda; dip the soda bead into this mixture and again fuse the bead plus adhering mineral powder thoroughly; cool the fused mixture; grind to a powder, dissolve in dilute hydrochloric acid; boil gently and if tungsten is present, a yellow powder will form as with the simple acid test. To confirm, add zinc or tin to the solution; boil gently and, again as with the acid test, the solution will turn blue if tungsten is present.

GEOLOGICAL OCCURRENCE OF TUNGSTEN MINERALS.

Tungsten minerals occur in all types of rock including both igneous and sedimentary rocks, and in placers. Deposits that occur in sediments usually have some close and obvious areal relationship to igneous rocks; although deposits that are far away from granitic sources have been recently described from Bolivia by Ahlfeld (IV, 1938). The types of deposits with igneous affiliations include magmatic segregations, pegmatites, high temperature replacement (pyrometasomatic) deposits, and veins. With the exception of magmatic segregations tungsten-bearing representatives of all these types occur in British Columbia.

Magmatic segregations: Magmatic segregations are deposits that have been formed by concentration of the ore minerals in the molten magma prior to its consolidation as an igneous rock. The ore-minerals usually occur as knots or segregations within the enclosing igneous rock. Tungsten minerals are found in such deposits but only infrequently and in small amounts. An occurrence has been described (I, Hess, 1917, p. 37) from the Whetstone Mountains, Arizona, where small crystals of wolframite are distributed through potash granite. No deposit of this type has been reported from British Columbia.

Pegmatites: Pegmatites are vein-like masses composed of coarsely crystallized minerals, of which quartz, feldspar and mica are much the commonest. Some pegmatites have been found to contain small amounts of tungsten minerals, but seldom in commercial amounts. Such occurrences have been reported from pegmatites in the Black Hills area of South Dakota (I, Lovering, 1933, p. 666) and at Oreana, Nevada (V, Kerr, 1938, p. 390). Scheelite in what appears to be pegmatitic material is found in British Columbia on Thornhill Mountain in the Terrace area. (This report p. 39).

High-temperature replacement (pyrometasomatic) deposits: High-temperature replacement (pyrometasomatic) deposits of tungsten have been formed by the replacing action of mineral-bearing solutions emanating from a cooling granitic magma, on limestones, and to a less extent on other sedimentary and igneous rocks. The altered rocks are characteristically replaced by calcic silicate minerals such as garnet, epidote, diopside, calcite and in tungsten deposits, by scheelite. The replaced area of rock is commonly referred to as a calcic-silicate zone. Owing to the vagaries of the replacing solutions, the form of such deposits is often irregular and the ore-bodies short and discontinuous. In a few places the replacement has been localized by tabular limestone beds giving rise to long simi-

larly shaped ore-bodies such as at the Stark and Humboldt mines near Mill City, Nevada. In prospecting for scheelite in calcic-silicate zones it should be remembered that such zones, by virtue of their mode of formation occur at or near the contact of limestones and small granitic intrusives.

The most important deposits of this type are the Humboldt and Stank Mines of the Nevada Massachusetts Company at Mill City, Nevada, (V, Kerr, 1934) and several others near Bishop in Inyo County, California, (V, Hess and Larsen, 1921). As compared with the numerous discoveries of this type of deposit in the United States, only four have been found in British Columbia. Three of these are in the Beaverdell area, (see this report p. 79) and the other, in the Twenty-three Mile Camp area, (see this report p. 78); in these deposits small amounts of scheelite are found as disseminated grains throughout calcic-silicate rocks.

In 1939 such deposits were responsible for the largest part of the United States tungsten.

Veins: Important amounts of tungsten minerals also occur in many quartz veins. The tungsten-bearing veins include several structural and mineralogical types that may be grouped as are other quartz veins, into three main classes according to temperatures prevailing at the time of mineral deposition. For convenience of description these vein-types are referred to as low, (epithermal), intermediate (mesothermal) and high (hypothermal) temperature veins.

As a result of having formed relatively close to the surface and under light load or pressure, the structure and texture of low-temperature veins are often characteristic of the class. The vein-walls are often irregular and the vein-matter frozen to the wall-rock. Splitting is a feature of some of the veins and as a result, this type tends to be short and of variable strike and dip. Texturally, extreme brecciation, commonly ascribed to veins formed under light load, and a fine rhythmic banded filling, characterize most of these veins.

The mineralogy of low-temperature veins is distinctive. Quartz is usually fine-grained to dense and occurs as finely banded material representing repeated stages of deposition. Minerals formed at a low temperature that are common in this type of vein but are not usually found in other types of deposits include: cinnabar, stibnite, realgar and chalcedony. High-temperature minerals such as magnetite, tourmaline, garnet and pyroxene are absent.

Low-temperature veins occur most frequently in regions of Tertiary or more recent volcanic activity, not necessarily in the lavas themselves, but often in the adjacent rocks.

Tungsten production from low-temperature veins ranked second in 1939 in the United States. The most important representatives of this type in the United States are the scheelite veins of the Atolia district, California, (V, Hulin, 1925, p. 77), the ferberite veins of Boulder County, Colorado, (I, Lovering, 1933, p. 669) and the huebnerite veins of the Silverton-Gladstone area in Colorado, (idem, p. 668). The only representative of this class in British Columbia is the Phillips' scheelite deposit in the Bridge River area (see this report pp. 73 - 77).

Intermediate temperature (mesothermal) veins commonly occupy fissures that are fairly regular in strike and dip. Faulting along the fissures has usually been common and as a result the vein-walls are often marked by films of gouge and are usually free. These veins do not possess the extreme brecciation found in some of the low-temperature veins. In texture they may or may not be banded, but they do not usually possess the fine, rhythmic banding that characterises low-temperature veins. Open spaces existed at the time of formation of some of the veins, and vugs lined by crystals are common.

The mineralogy is not strikingly characteristic. Many of the minerals are common to both low- and high-temperature veins. However, such low-temperature minerals as cinnabar, stibnite and chalcedony, and such high temperature minerals as molybdenite, cassiterite and tourmaline, are absent.

In only a few places has tungsten, mainly the mineral scheelite, been found in intermediate-temperature veins in quantities sufficient to justify mining for tungsten alone; usually such veins are mined for their gold-silver, or base-metal, content. As a result, the production of scheelite from veins of this type has been small.

Tungsten-bearing veins of the intermediate temperature type (idem p. 667-668) include the copper and the gold-silver veins of Butte, Montana, many of which carry a small amount of huebnerite, the quartz-sphalerite-galena veins of the Patterson Creek district, Idaho, which contain some huebnerite and the scheelite-bearing gold veins from near Murray, Idaho.

The chief representatives of this vein-type in British Columbia are the gold-quartz veins of the Cariboo district

(see this report pp. 57-59), which in addition to galena-sphalerite and pyrite, frequently contain scheelite. British Columbia's only producer of scheelite concentrates the Columbia Tungsten's property near Wells, is considered by the writer, to belong to this type. (see this report pp. 59 -68).

High-temperature hypothermal veins are commonly lenticular. Fissuring, though sometimes present, is not common, and as a result the vein-matter is usually frozen to the walls. Siliceous replacement of wall-rock is common and because its extent is apt to vary, any lenticularity of such veins due to a fissure of varying width is further emphasized by wall-rock replacement.

The mineral assemblage is characterised by the presence of molybdenite, cassiterite, pyroxene, amphibole, garnet, ilmenite, magnetite and tourmaline; these minerals occur only rarely in the other vein-types. Examples of tungsten-bearing veins of the high-temperature type in the United States (I, Lovering 1933, p. 666) include the quartz-wolframite deposits in the Deer Trail district, Washington and quartz-wolframite veins near Jardine, Montana. The best examples in British Columbia are the quartz-ferberite-scheelite veins on the Red Rose and Black Prince in the Hazelton area. (see this report pp. 68 - 52.)

In general, production from the high temperature types of tungsten vein has not been large to date.

FLUORESCENCE AND ITS APPLICATION TO THE STUDY OF SCHEELITE DEPOSITS.

The detection of scheelite by its fluorescence in ultra-violet light has of late received considerable deserving attention.

Definition of fluorescence. Fluorescence is the ability of a substance, e.g., a mineral, to absorb invisible ultra-violet wave-lengths of light and to emit visible wave-lengths. Physicists are still somewhat uncertain as to the exact cause of fluorescence. However, they seem to agree in the explanation given in the following sentences. Minerals, in common with other substances are believed to consist of atoms, which are units too small to be visible as such, even under high power microscopes; their existence and structure are deduced by the physicists by reasoning from the electromagnetic

behaviour of matter. According to the Bohr theory (I. Radley and Grant, 1933, p. 5), atoms are believed to consist of a central nucleus around which electrons revolve in orbits. If an atom is exposed to ultra-violet radiations an electron may be made to pass from an inner orbit to an outer one; energy furnished by the ultra-violet light, is absorbed during the passage. In this disturbed condition the atom is unstable and in order to re-establish itself, the displaced electrons tend to return to their inner orbits. During their return, the electrons emit the energy in the form of radiations absorbed in their displacement outwards. These radiations of wave-lengths of light are visible to the human eye and are known as fluorescent light. Those substances or minerals capable of emitting such light when exposed to ultra-violet radiations, are known as fluorescent substances or minerals. Ultra-violet wave-lengths are generally considered to be those lying between 136 Ångström units (1 Ångström unit equals 10^{-8} cm.) and 4000 Ångström units, whereas visible wave-lengths of light lie between 4000 and 8000 Ångström units (Radley and Grant 1933 chart facing p. 2).

Fluorescent minerals. Not all minerals fluoresce in ultra-violet light, or even all varieties of the same mineral. The reason for this is not known. Some think that it is due to minute amounts of impurities present in different mineral varieties; these amounts are usually so small that they can only be determined spectrographically.

The natural colour of a mineral cannot be correlated with the colour of its fluorescence; some colourless varieties of the same mineral fluoresce with a brilliant hue, whereas some coloured varieites of the same mineral do not fluoresce. The same mineral will often show different intensities and colours of fluorescence depending on the source of the ultra-violet light. Of the three main sources of ultra-violet light, namely, the argon bulb, iron arc and mercury vapour arc, the latter appears to produce the strongest fluorescence in the largest number of minerals. The improved results from this type of lamp appear to be due to a greater intensity of the shorter ultra-violet wave-lengths emitted, the correlation between these shorter wave-lengths and an increased excitation of fluorescence in minerals.

Approximately 125 different minerals have been shown to fluoresce under a strong source of the shorter ultra-violet wave-lengths. A list of those minerals which fluoresce most easily under almost any source of ultra-violet light includes the following: some ambers, autunite, curtisite, dakeite,

some fluorites, hyalite opal, semi-opal, petroleum, scapolite, some sphalerite and willemite. It is to be noted that scheelite is not included in this list. It will only show suitable fluorescence under a strong source of ultra-violet light such as the high intensity iron spark or mercury vapour lamp.

The colour of the fluorescence of scheelite varies somewhat with the type of lamp used. In light from an iron spark most scheelite is reported to fluoresce a blue or light bluish colour whereas under a mercury vapour lamp of the type used by the British Columbia Department of Mines, most of the British Columbia scheelite examined in its laboratory fluoresces a brilliant oyster-white.

Sources of ultra-violet light. In practice, ultra-violet radiations are obtained from three main sources, namely, argon-glow lamps, "strong-arc" and mercury vapour lamps.

Argon-glow lamps are small, gas-filled bulbs similar in shape and size to old-fashioned electric light bulbs of low wattage. These bulbs have an electrode at each end filled with argon gas. The ultra-violet light is emitted as a relatively steady violet-coloured glow that results from the discharge of electrons through the argon gas between the two electrodes.

Argon-glow bulbs may be used on alternating or direct current; on alternating current they may be connected to the ordinary lighting circuit without the use of a transformer. The bulbs are approximately 60 cents each and as only about ten are necessary for a suitable effect on a few minerals, they are a relatively inexpensive source of ultra-violet light. Inasmuch as the ultra-violet emanations from these lamps are of a fairly long wave-length, reported to be between 3,300 and 3,700 Ångström units, not all minerals will fluoresce in their light, and scheelite is one of those minerals. Argon-glow bulbs are, therefore, not suitable for the detection of scheelite.

The construction of the strong-arc type of lamp has been described by Vanderberg (I, 1935, p. 2). He summarizes the constituent parts as follows:

1. Transformer to step 110 volts A.C. up to 4500 volts.
2. A mica condenser that has a capacity of 0.004 microfarad at 3,500 volts.
3. A spark gap with adjustable and replaceable iron electrodes.

According to Vanderberg, this lamp may be purchased for $35.00.

The wave-length of the ultra-violet light emitted by a high tension spark between iron electrodes is reported to lie within the range of 4270 to 2100 Ångstrom units. Because of the possession of the shorter wave-lengths below 3000 Ångstrom units, such light will fluoresce many more minerals than the argon-glow lamps, particularly scheelite. Most scheelite is reported to fluoresce to a light blue in light from such a source.

Inasmuch as this type of lamp is not easily adaptable for use with light-weight batteries, it is not particularly useful in general field-work where portability is a first requirement.

Mercury vapour lamps are constructed so that an electrical discharge is sent through mercury-vapour between metallic mercury electrodes. This type of lamp is perhaps most suitable for general purposes and particularly for the detection of scheelite. This mineral fluoresces brilliantly in such light, usually a bright oyster-white and bluish-white and sometimes a light-orange.

Three main types of mercury-vapour lamps at present in use, have come to the writer's attention, namely:

1. A mercury-vapour tube manufactured under the trade-name "Nico" and sold through Ward's Natural Science Establishment, Rochester, N. Y.
2. A high-intensity mercury-vapour arc enclosed in a bulb, also sold through Ward's Ltd.
3. A coiled quartz tube lamp sold by Ultra-Violet Products, Inc., of 6158 Santa Monica Blvd., Los Angeles, Cal. under the trade-name "Mineralight."

The Nico lamp is described by Ward's in their Catalogue No. 39, 1938, as follows:

> "This lamp, which is a modification of the Cooper Hewitt lamp, has been completely re-designed; the Mercury vapour tube, made of lead glass to which small quantities of nickel and cobalt salts have been added, gives greatly improved effects. The tube is provided with universal screw base terminals and is mounted to an Alzac aluminum reflector which permits the maximum

reflection of ultra-violet light. The reflector and tube may be mounted in any position from 7° above horizontal to within 10° of the vertical plane.

"The auxiliary unit, containing the transformer, is separate from the reflector permitting it to be placed at some distance from it. A 6 or a 9 foot extension cable is provided which permits the reflector and auxiliary to be separated by this distance. The latter is provided with hooks, bottom cover and tilting brackets. This new equipment is so flexible in design as to meet practically every type of installation. The lamps are attractively finished in mahogany surah. The transmission of the new Nico lamp is between 3030 and 4520 A.U., a much greater range of wave-lengths than that emitted by the old style lamp."

The quoted prices, as of 1938 and f.o.b. factory at Hoboken, range from $50 to $55, depending on the length of tube desired and power available. The tubes range in length from 22 to 50 inches.

This type of lamp is very suitable for permanent installation but not particularly portable and therefore not so adaptable to general field use.

A portable bulb-lamp operating from a 110-115 volt alternating current circuit is also sold through Ward's at a catalogue list-price of $32.50. This unit has the advantage of portability and is less expensive than the Nico unit.

In their catalogue No. 38, 1938, Ward's describe this unit as follows:

"The light source is a high-intensity Mercury vapour arc enclosed in a bulb. This lamp operates from a reactive transformer producing 440 volts for starting and 250 volts at the arc terminals at a normal arc current of 0.4 amperes.

"The transformer with switch is in a steel box that also acts as a base. From the base projects an 18-inch gooseneck which supports the lamp. The lamp bulb is covered with a cylindrical heat-resisting filter. A chromium reflector shields the eyes from the intense radiations and also concentrates the ultra-violet light. The lamp must be burned about 5 minutes before the maximum brilliance is obtained.

When it is once turned off it will not operate again until it has cooled. This usually takes about 5 minutes. The bulb must be operated in the horizontal position. Its life is about 500 hours."

A mercury-vapour lamp that consists of a coiled quartz tube within a suitable housing is made by Ultra-Violet Products Inc., 6158 Santa Monica Blvd., Los Angeles, California, under the trade name "Mineralight." This lamp transmits an abundance of the shorter wave-lengths of ultra-violet light, especially those in the wave-length region of 2536 Ångstrom units, the wave-length of one of the principal lines in mercury. Because of the abundance of shorter wave-lengths in the emitted light, this lamp excites fluorescence in a large number of minerals and a very brilliant fluorescence in scheelite.

The company makes several types of this lamp varying in size and portability. All lamps may be used on an ordinary lighting circuit in conjunction with a suitable transformer, or may be operated from batteries and transformer. The company makes a unit that weighs only 28 lbs. complete with batteries and transformer and may be carried on a packboard so that it is particularly suitable for field work. Depending on the size of the lamp and the accessories desired, the price quoted by the company for their various lamps in their Bulletin No. 12-39-5 ranges from $39.75 to $155.00.

Use of ultra-violet light in detection of scheelite.

Ultra-violet light has recently been widely used by geologists and mine operators in the detection of scheelite. Inasmuch as scheelite is earthy in lustre and varies considerably in shades of white, buff and orange, it is not always distinguishable in ordinary or white light, from gangue minerals such as quartz, carbonates and some lime-silicates. In a strong source of the shorter wave-lengths of ultra-violet light, however, all scheelite fluoresces, whereas quartz never does and the carbonates only rarely and then usually to a strong pink fluorescent colour easily distinguishable from the usual oyster-white of scheelite. Because of the brilliant fluorescence of scheelite, small areas down to pin-point dimensions, are readily recognizable on exposed surfaces of mineralized material.

In quartz veins or veinlets in which the scheelite is white in colour and occurs in small grains, it is usually readily detected only by its fluorescence in ultra-violet light.

Scheelite that occurs intimately mixed with sulphides, particularly in a vein in which the proportion of sulphides to gangue is large, is most easily seen by the use of ultra-violet light. The variety and shades of colours possessed by the many different minerals found in calcic-silicate zones, makes the field detection of small amounts of scheelite difficult in ordinary light, but relatively simple if made in ultra-violet light.

The detection of scheelite in any new occurrence should always be checked chemically or microscopically. It may be noted that willemite, a mineral commonly occurring with scheelite in calcic-silicate zones, fluoresces strongly and care must be observed that this mineral in particular is not mistaken for scheelite.

In the use of an ultra-violet lamp the best results are obtained in total darkness, especially in underground workings. However, during the daytime an ordinary room which has been darkened will be found suitable.

In the examination of surface workings and outcrops for scheelite, apart from deposits where scheelite is readily recognisable, the writer found that a study of the actual outcrops or workings with the lamp in the field is much more suitable than the method of taking specimens back to camp for study at night or in a darkened room. Examining surface workings at night may be inconvenient, but the results are usually worth it. By observation of the actual outcrop with a lamp, the distribution of the scheelite either within a vein or in an irregular replacement area, may be studied and any trends or directions of improved mineralization noted. In addition, the usefulness of sampling may be determined, and if found necessary the nature of the material may be studied, and thus blind sampling avoided.

Ultra-violet lamps are used quantitatively in actual mining and milling operations to make rough estimates of the amount of scheelite present either in a working face or at various places in a mill circuit. After a certain amount of correlation is made between the appearance of an ore-face and assays from the same face, it is possible to tell whether or not the grade of mineralization as seen in ultra-violet light constitutes ore. The use of ultra-violet lamps in routine work of this kind minimizes the amount of rather expensive tungsten assaying necessary. In milling operations, ultra-violet lamps are most commonly used in estimating the percentage of scheelite in products from such machines as jigs,

tables and magnetic separators in order to test the efficiency of the machine and to note any changes in the contents of the mill feed. The speed and cheapness with which these observations can be made as against usual long and costly assaying methods, permits repeated checking and, therefore, an increase in total efficiency.

All Plates at the end of the Bulletin, with the exception of Plate IV, were taken under fluorescent light.

MILLING.

Two main practices characterise the milling or concentration of tungsten ores: (1) gravity methods are used either wholly or in a large part, (2) stage crushing with rolls rather than with ball-mills is customary because of the brittleness of the tungsten minerals and the resultant great tendency to slime.

The ore is usually broken down by primary crushing in Blake-type crushers, followed by stage crushing in sets of rolls.

Thorough classification of the ground ore is essential in order to reduce the percentage of slimes. This is done according to grain size as the feed passes through the mill, the slime being removed from the sand as continuously as possible.

Jigs are used to definite advantage when the tungsten minerals occur in fairly large grains and are available for separation as clean material at an early stage in the grinding of the ore. The circulating load is thereby decreased and the chances for sliming are also reduced.

Tables are extensively used on the fine-grained material. In order that loss from overloaded tables be kept low, ample table capacity should be provided.

Flotation cells are standard equipment in nearly all present-day mills. They are used to remove the fine sulphides from the raw table concentrates. Ordinary oil flotation methods separate scheelite from the sulphides. Of late, soap flotation has been used to separate scheelite from non-magnetic gangue.

Recovery of tungsten minerals from slimes is always a problem. In some mills slimes have been treated on vibratory

tables with a fair degree of success. Recently, considerable experimental work has been done with flotation cells for recovering scheelite from slimes and mill-tailings (II, Leaver and Royer, 1938). A scheelite concentrate can be obtained, but the difficulty seems to be in recovering a product sufficiently high grade to ship.

Some tungsten ores contain a considerable amount of pyrite. Common practice (II, Heizer, 1934, p. 838) is to concentrate the pyrite with the scheelite and then to remove the fine pyrite by flotation and the coarse pyrite by a magnetizing roast followed by magnetic separation with machines of the Wetherill or Ding type. These machines may also be used to subtract the minerals garnet and epidote from the scheelite concentrate.

ECONOMICS OF TUNGSTEN.

Specifications of marketable product.

Scheelite is customarily marketed as a concentrate or high-grade cobbed ore that contains 60 per cent. or more tungstic oxide (WO_3). Payment is made on the basis of so much per short-ton unit of 20 lbs. in the United States and Canada, and per long-ton unit of 22.4 lbs. in London, and per metric-ton unit of 22.04 lbs. in France and Germany.

Although all buyers do not require adherence to exactly the same specifications for tungsten ores and concentrates, the general requirements are nearly similar. To illustrate the minimum grades of ore and the maximum allowable impurities acceptable, the writer has chosen one list of specifications as set by the United States Treasury Department, and another list as commonly used by buyers in the London market.

The specifications as set by the United States Treasury Department, procurement division for Tungsten Ores as of August 24, 1939, are as follows:

Tungstic oxide (WO_3)		60	per	cent.	min.
Tin	Sn	1	"	"	max.
Copper	Cu	0.05	"	"	"
Phosphorous	P	0.035	"	"	"
Arsenic	As	0.5	"	"	"
Antimony	Sb	0.05	"	"	"
Bismuth	Bi	0.12	"	"	"

Molybdenum	Mo	0.40	per cent. max.
Sulphur	S	0.50	" " "

The specifications as set by most London buyers are as follows:

Tungstic oxide (WO_3)		60	per cent. min.
Tin	Sn	1.5	" " max.
Arsenic	As	0.2	" " "
Sulphur	S	0.3	" " "
Copper	Cu	0.1	" " "

Small deviations from these requirements are permitted but with a consequent alteration in the basic prices for tungsten. The nature of these allowances is as indicated in the following paragraphs quoted from the standard contract for tungsten ore from China: (this is an excerpt from a communication dated November 22, 1939, from the Canadian Government Trade Commissioner at London).

"Quality. In case of deviation regarding quality and/or contents buyers have no right to reject the goods, provided the WO_3 contents are not under 55 per cent. and/or the As contents are not over 2 per cent., but they have to take delivery with the following allowances to be granted by sellers.

WO_3 contents. In case the WO_3 contents should be under 65 per cent. the following allowances are to be made:

for each per cent. WO_3 under 65 per cent. down to and including 60 per cent. 3d)	per unit WO_3 per ton of 1016 kilos nett dry weight fractions in proportion.
for each further per cent. WO_3 under 60 per cent. down to and including 55 per cent. 6d)	

If the WO_3 contents should be less than 55 per cent. buyers have the option of rejecting the goods or of accepting same at an allowance mutually agreed upon or (failing agreement) fixed by arbitration as below mentioned, such option to be declared by buyers within 8 days after receipt of the awway certificate.

Sn contents. If the Sn contents exceed 1.5 per

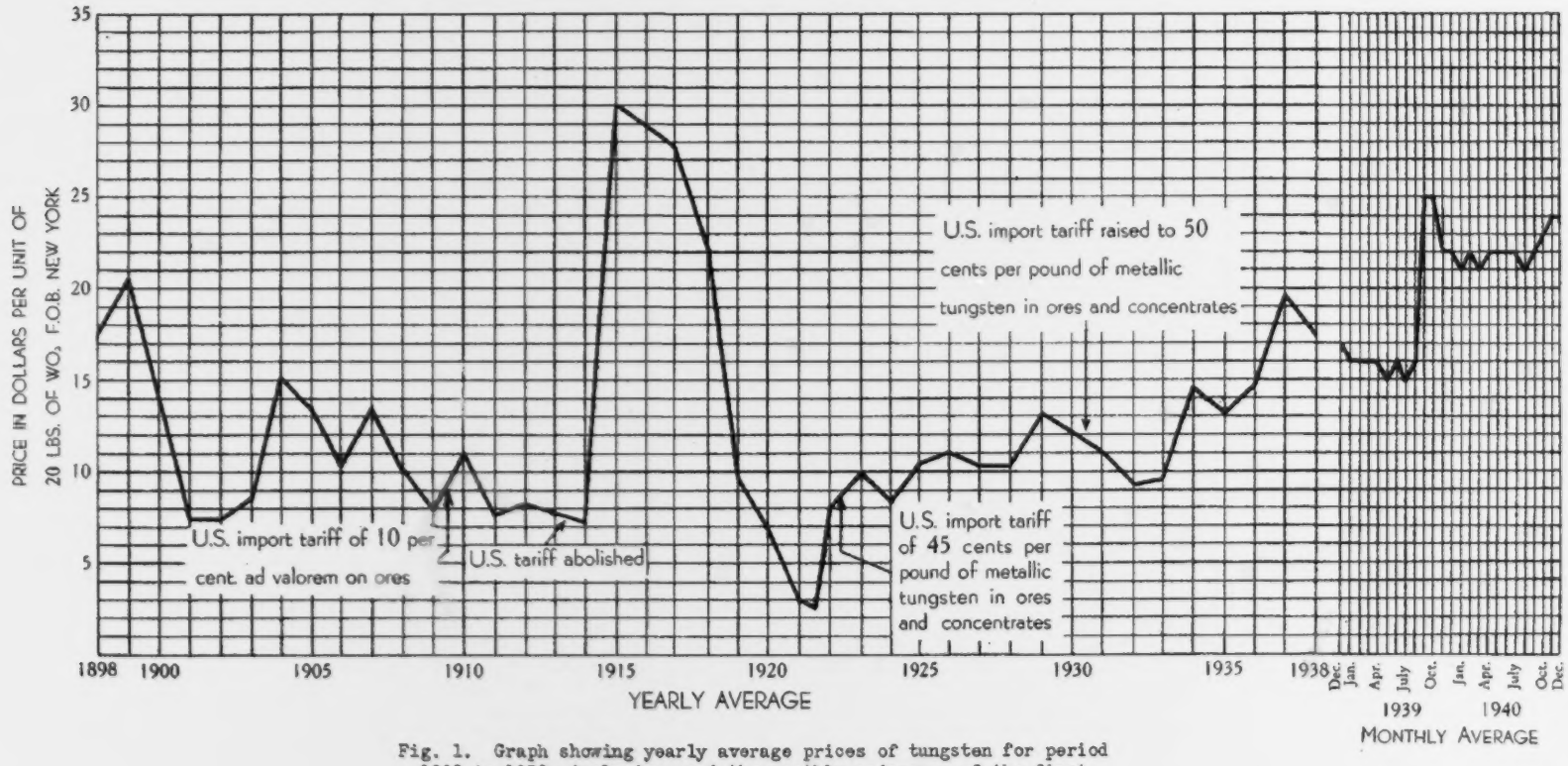

Fig. 1. Graph showing yearly average prices of tungsten for period 1898 to 1938, inclusive, and the monthly prices as of the first few days of each month for period December, 1938, to December, 1940. Sources of information from: Hutchinson and Mann (1928, p. 46); Minerals Yearbook, U. S. Bureau of Mines (1936, p. 448; 1939, p. 623); Engineering and Mining Journal, issues for months December, 1938 to December, 1940.

cent. but do not exceed 1.6 per cent. buyers have to accept the goods as good delivery. Should the Sn contents exceed 1.6 per cent. sellers have to allow to buyers for each one tenth per cent. over 1.5 per cent. 2d. per unit WO_3 per ton of 1016 kilos nett dry weight--fractions in proportion.

As contents. Sellers have to grant buyers the following allowances:

If the full As contents exceed 0.2 per cent. up to and including 0.25 per cent. 3d)	per unit of WO_3 and per ton of 1016 kilos nett dry weight.
If the full As contents exceed 0.25 per cent. up to and including .30 per cent. 6d)	
If the full As contents exceed 0.30 per cent. up to and including .70 per cent. 9d)	

For each further 1/2 per cent. or part thereof over 0.70 per cent. an additional 3d. per unit WO_3 per ton of 1016 kilos nett dry weight.

If the assay exceeds 0.2 per cent. As a second assay is to be made by another laboratory mutually agreed upon by the two parties, the mean of the two results being final. The cost of the second assay is also to be equally divided between buyers and sellers.

If the As contents exceed 2 per cent. buyers have the option of rejecting the goods or of accepting same at an allowance mutually agreed upon or (failing agreement) fixed by arbitration as below mentioned, such option to be declared by buyers within 8 days after receipt of the assay certificate. Buyers have the right to deduct the before-mentioned allowances from the payment of the final invoice."

Prices. The price paid for tungsten on a basis of content of tungstic oxide (WO_3) varies. Ores from different districts are quoted at different prices, the premiums or discounts varying with the buyers. Furthermore, the grade of concentrates and limitations of impurities vary with the requirements of the individual buyer and at times with the market. In periods of great demand for tungsten, lower grade

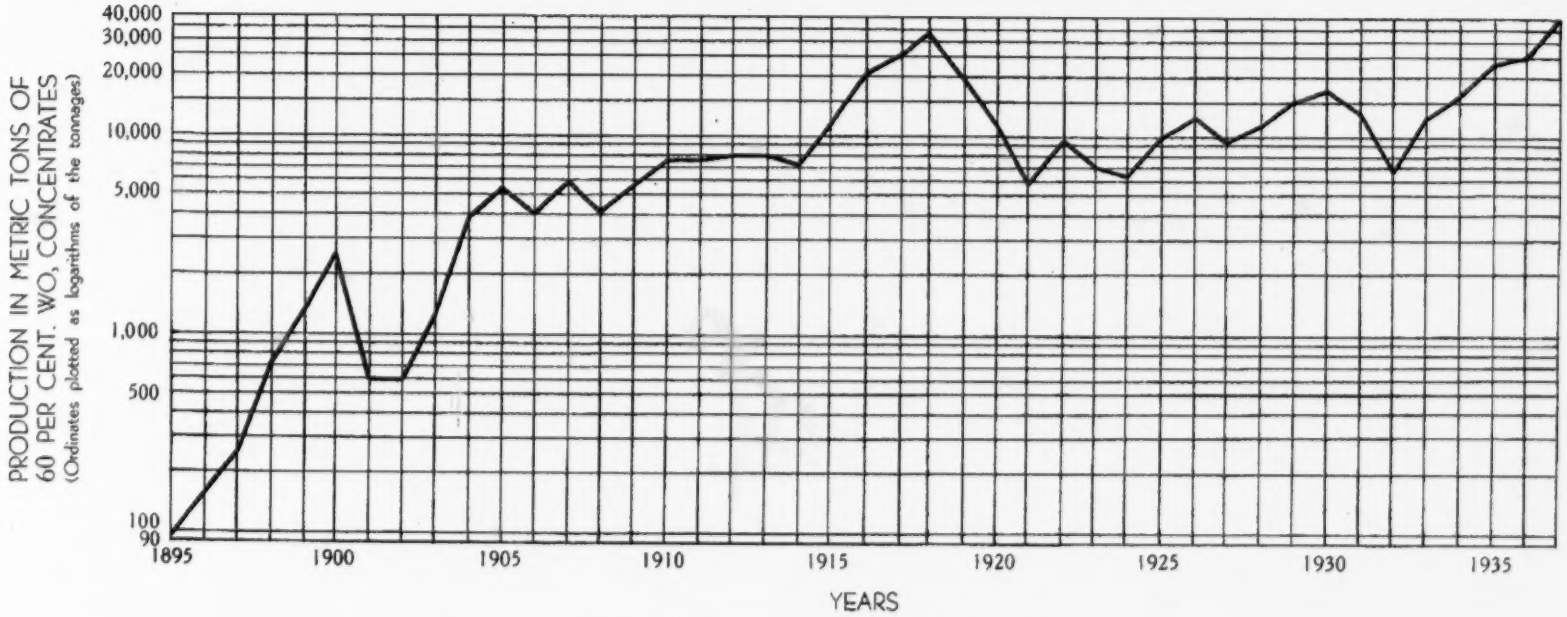

Fig. 2. Logarithmic curve showing world production of tungsten by years from 1895 to 1937, inclusive. Data compiled from Mineral Industry, by G. A. Roush (1931, p. 564); Minerals Yearbook, U. S. Bureau of Mines (1932, pp. 276-277; 1936, p. 453; 1940, pp. 14-15); Hutchinson and Mann (1928, p. 46).

ores can be sold, but at a discount. The specifications given above are usually closely adhered to and will serve as a guide in determining the value of a concentrate or high-grade cobbed ore.

The price graph in (Fig. 1), shows the yearly average price of tungsten for the period 1898 to 1938, inclusive, and the monthly price as of the first few days of each month for the period December 1938 to December 1940, inclusive. The prices are given as f.o.b. New York rather than f.o.b. London, because the economics of tungsten production in the United States is more nearly similar to that of Canada than of Burma or China, the source of most of the tungsten supplied to the London market.

The prevailing price in Canadian markets for tungsten approximates the New York price less the United States import tariff of $7.931 per short-ton unit of tungstic oxide (WO_3) in ore and concentrates. The current quoted price (E. and M. J. Metal and Mineral Markets, New York, Nov. 28, 1940) for tungsten ore, f.o.b. New York is $24.00 nominal per short-ton unit of tungstic oxide (WO_3) for domestic (United States) scheelite ores of good known analysis in carload lots. The prices on Chinese and Bolivian ores, duty paid, f.o.b. New York ore are $24.50 and $23.50 to $24.50, respectively.

Mineable Grades. The figures for mineable grades of tungsten ores depend on several factors. In a prospect or small operation they depend on whether, (1) the ore is mined selectively and the tungsten mineral cobbed from the gangue and wall-rock and shipped as high-grade raw ore, or (2) whether the vein-matter is mined across a width of say 3 feet and the tungsten minerals plus gangue and rock mined and milled to a tungsten concentrate of shipping grade.

Because tungsten is a relatively high-priced metal it permits hand-cobbed ore to be shipped direct. On a small scale it is possible to sort ore from a quartz-scheelite or quartz-carbonate-scheelite vein as little as 1 inch in thickness. In general for hand cobbing, the scheelite should constitute about one-quarter of the vein-matter and be in grains not smaller than 1/2-inch diameter and not intimately mixed with the gangue. An ultra-violet lamp is very useful as an aid in distinguishing scheelite from waste in any hand-sorting operation.

The method of mining lower-grade tungsten ore for milling is in general similar to that of other ores. The mineable

grade depends on whether or not the ore-body is an irregular replacement (pyrometasomatic) type or a relatively more regular vein-type. and if the latter, whether it is a single vein or several veins or veinlets close enough together to be mined as a whole. The nature of the ore-body will determine the mining method to be adopted.

In order to give some idea of the grade of ore and mining and milling costs in operating tungsten mines, the writer has gathered pertinent data from several mines in the United States and from two in New Zealand (see Table II). When considering United States costs in relation to tungsten mining in Canada, it must be borne in mind that the United States tungsten is protected by an import tariff of $7.931 per short-ton unit of tungstic oxide (WO_3) in ore and concentrates.

Production. The world output of tungsten by countries producing over 100 tons in 1938 is given in Table III, and a graph showing world production from the year 1895 to 1937 is given in (Fig. 2).

TABLE II - SUMMARISED OPERATING DATA ON SEVERAL TUNGSTEN PROPERTIES

Property or Mining Company	Approx. Grade of Ore, in Percent WO_3	Mining Method	Mill Capacity tons per 24-hour day	Approx. Mining Costs Dollars per ton	Approx. Milling Costs Dollars per ton	Total Costs Dollars per ton	References (see key at bottom of Table)
NEVADA							
Nevada Massachusetts Co., near Mill City	About 1 per cent.	Shrinkage	About 350	3.94	1.24	5.18	1; 2. 1938.
Silver Dyke Mine, Mina.	About 1 per cent.	Shrinkage	50	3.69	2.64	6.33	1
CALIFORNIA							
Atolia Mining Co., Atolia.	1.98	Shrinkage and open-stope	100		1.22		1; 2, 1940.
Round Valley, Bishop	0.5	Glory-hole	75-120	0.76	0.85	1.61	1
COLORADO							
Cold Springs Mine, near Nederland	Mine-run 0.9 per-cent; sorted to 5.72 per cent.	Cut and fill.	About 25	17.172 per ton of sor-ted ore.	6.015	23.00	1
NEW ZEALAND							
Golden Point Mine Otago	Sorted to 65 per cent. rejects milled		30	1.86	1.38	3.53 (total costs)	3

References: Key No.

1 U.S. Bur. Mines, Information Circular No. 6852, 1935.
2 U.S. Bur. Mines, Minerals Yearbook.
3 Gudgeon, C.W. (1916) Gold-scheelite ore in New Zealand, Mining and Scientific Press, Vol. 113, p. 136.

TABLE III - World Production of Tungsten Ores in Metric Tons of Concentrates containing 60 per cent., Tungstic Oxide (WO_3) for Countries Producing over 100 tons in 1938; and arranged by countries in order of importance during the year 1938.

(As abstracted from compilation by M.T. Latus, U.S. Bureau of Mines, Minerals Yearbook, 1940, pp. 630-631).

Country	1938	1939
China	13,387	11,580
Burma	6,334	'
Portugal	2,810	3,851
United States	2,761	3,889
Bolivia	2,530	3,334
Argentina	1,195	'
Malay States	1,000	297
Indo China	545	'
Australia	1,185	859
Southern Rhodesia	329	270
Cornwall, England	258	'
Thailand	251	'
Sweden	180	'
Peru	170	'
Union of South Africa	127	100
' Data not available.		

Consumption. The apparent consumption of tungsten by the principal users of the metal is given in Table IV. The figures in this table are the results of calculations made from the figures for production, exports and imports of the various countries as given in the Statistical summary of the Imperial Institute, (III, 1939, pp. 416-420), Mineral Raw Materials (1937, p. 217) and from the Minerals Yearbook, U.S. Bureau of Mines (III, 1939, pp. 620-629).

TABLE IV - Apparent Consumption by Countries of Tungsten by the Principal Users of the Metal

Country	Consumption (reduced to equivalent of 60 per cent. tungstic oxide, WO_3) In Metric Tons				Per cent. of Consumption by Countries Listed			
	1934	1936	1937	1938	1934	1936	1937	1938
Germany	4,700	10,060	13,000	16,340	27.0	38.3	41.0	60.5
United Kingdom	3,900	10,260	10,100	7,750	22.4	39.3	31.9	28.7
United States	3,020	5,850	8,580	2,910	17.5	22.4	27.1	10.8
Belgium-Luxemburg	2,100				12.1			
France	1,800				10.3			
U.S.S.R.	800				4.6			
Japan	1,070				6.1			

USES OF TUNGSTEN.

Tungsten is consumed mostly in alloys used in the manufacture of cutting tools and dies. Such alloys retain their hardness and strength at high temperatures and can therefore take a heavier cutting load on harder materials than the ordinary carbon steels.

The following four types of tungsten alloys are used either for the manufacture of dies or cutting tools or both:

1. cemented tungsten carbides,
2. high temperature tool steels,
3. stellites, and,
4. carbon-free-iron-base tungsten alloys.

Cemented tungsten carbides are alloys of tungsten, carbon and cobalt produced by methods of powder and metallurgy. In the United States the carbides are manufactured under the trade names "carbaloy," "ferthite," ferthalloy" and "dimondite." Powder metallurgy is becoming a very important consumer of tungsten and for that reason it will be discussed somewhat more fully than other uses.

In view of the general assertion that powder metallurgy is a recent development, the following quotation from Mining and Metallurgy, American Institute Mining and Metallurgical Engineers, New York, for October 1940, p. 478, in reference to a powder metallurgy conference held at the Massachusetts Institute of Technology in Cambridge, Massachusetts, U.S.A. is of interest:

> "Cyril S. Smith opened the conference with a challenge to any claim that powder metallurgy is something of a recent development, stating that the art could be called at least 5,000 years old; iron was made by compressing powder as early as 700 B.C., and Indian smiths of 1,600 years ago fabricated articles of some 6 1/2 tons gross weight by compressing and welding, a size of article that modern powder metallurgists have not yet equaled."

Sykes (1938, pp. 1-2) has summarized the principal steps in the manufacture of cemented carbide alloys as follows:

"1. Formation of the metal carbide in the form of powder by heating a mixture of carbon and the metal powder or oxide for several hours at a temperature between

1500 degrees and 2400 degrees C., usually in a carburizing atmosphere.

2. Intimate mixing of this carbide powder with the binding metal, usually cobalt or nickel, also in the form of powder.

3. Compressing this mixture in steel molds of various designs at a unit pressure of from 15 to 30 tons per square inch.

4. Initial sintering in some inert atmosphere, such as hydrogen, at a temperature of 800 degrees to 900 degrees C., to impart to the pressed metal sufficient strength for handling and shaping.

5. Final sintering at a higher temperature (in the range of 1400 degrees to 1600 degrees C.), which results in a considerable diffusion of the components and a real alloying action. This operation is also carried out in an inert or carburizing atmosphere."

Cemented tungsten carbides cannot be profitably used for all types of dies and cutting operations.

Sykes (III, 1938, pp. 9-10) has summarized the best uses of the different carbides as follows:

"The commercial success of a new alloy depends largely upon the judicious selection of its applications in the field of industry. While physical and mechanical properties may point the way to suitable uses, the final decision must be made from service records extending over long periods of time.

Upon the basis of such experience, the alloys of tungsten carbide and cobalt that have been described thus far fall into several classes of service, which are determined by the cobalt content, as might be expected. The 13 per cent. Co grade is employed extensively in the form of large dies for drawing, extrusion and shaping operations that demand a material of high strength. For smaller dies, and to a limited extent for cutting tools, a 9 per cent. Co grade is used. In the field of cutting tools for machining cast irons, most nonferrous alloys and many nonmetallic substances, the 6 per cent. Co alloy finds a wide variety of appli-

cations. In operations involving fine cuts at high speeds, a tool material containing as little as 3 per cent. Co is often employed. In such service, the higher resistance to abrasion contributed by the tungsten carbide constituent in the tool may be profitably utilized, since no excessive demands are made upon its strength or resistance to shock.

It will be observed that steel was omitted from the list of materials that can be profitably machined with tools of cemented tungsten carbide. The failure of tungsten carbide to cope with the cutting of steel appears to be associated with the higher cut pressures involved in such work, which lead to early failure of the tool by the phenomenon known as "cratering" or "loading." In this type of failure, fragments of the steel chip weld to the tool and break out small particles of the carbide alloy, in time causing the cutting edge to crumble."

Previous to the advent of cemented tungsten carbides, and still important, are high-speed tungsten steels, chiefly used for cutting tools. The usual composition of such steels is: tungsten, 18 per cent.; chromium, 4 per cent.; vanadium, 1 per cent. and carbon, 0.6 to 0.75 per cent. (III, Sykes, 1935, p. 387).

Stellite, an alloy containing tungsten, 3 to 17 per cent.; cobalt, 45 to 70 per cent. and chromium 28 to 35 per cent.; is also used for machine tools. Its chief virtue lies in its resistance to tarnish and corrosion, and it is, therefore, used in the manufacture of surgical instruments. Alloys that are also widely used in cutting tools are the carbon-free alloys of iron and tungsten containing, tungsten 20 to 30 per cent.; and cobalt, 30 per cent. Tungsten alloys of slightly different composition have been used for hack-saw blades and hot-forming dies.

Tungsten steels with varying amounts of tungsten have been used in the manufacture of armor plates and certain types of projectiles. Such steel has also been used in the lining for cannons.

Unalloyed, metallic tungsten is consumed in the manufacture of electric light and radio filaments. However, although many miles of thin filament wire are made yearly, the actual amount of tungsten used for this purpose is small.

A small amount of tungsten is used in the manufacture of various pigments and in the tanning of white leather.

CHAPTER II

WORLD DISTRIBUTION OF MAIN TUNGSTEN OCCURRENCES.

AFRICA

Southern Rhodesia. Southern Rhodesia produces tungsten from lode deposits of scheelite. In 1937 (III, Roush, 1937, p. 612) the chief mines were the Gold Valley, which produces scheelite as a by-product from operations for gold, the Scheelite and the Sequel. It is noted that the Sequel mine operated a 100-ton mill in 1937.

AMERICA, SOUTH

Argentina. Tungsten is one of the chief mineral products of Argentina, and this Republic ranked sixth in world production of tungsten during 1938. The most important deposits are in the Pampa Range in the Provinces of San Luis and Córdoba. The deposits are all lode and consist chiefly of wolframite with a smaller amount of huebnerite and scheelite in quartz veins. Cassiterite, mica, bismuthinite, molybdenite, pyrite and galena also occur in the veins. The ores in general range from 0.5 to 1.5 per cent. WO_3 (III, Roush, 1937, p. 607). Mining and transportation costs are relatively high.

Bolivia. Bolivia, ranking fifth in world tungsten production in 1938 and 1939, is the chief producer of South America. The Bolivian deposits, all lode, occur in the "tin-

belt" but they are, however, separate from the tin deposits. Most of the tungsten ore is wolframite, and only a small amount scheelite. The main deposits are in the Departments of La Paz and Uroro. Concerning the future of the Bolivian tungsten deposits, the following statement by Lilley (I, 1936, p. 431) is of interest: "Bolivia probably contains the largest quantity of developed medium-cost primary ore in the world."

ASIA

Burma. Burma, ranking second in 1938 in world production, produces most of the tungsten mined in the British Empire. The mineral wolframite is the main source of Burma tungsten. Although it occurs in alluvial and placer deposits, most of this mineral is obtained from lode deposits. Much of the wolframite is associated with cassiterite, and many mines produce both tungsten and tin. Because of this dual production, the majority of the tungsten-tin mines have been able to operate fairly continuously even when prices were low. Those properties producing only tungsten, have usually been unable to operate except when good prices for the metal prevailed. Most of the Burma tungsten (IV, Brown, pp. 142-145) comes from the Tavoy and Yamethin districts, the Tavoy being the more important district of the two. The largest mines in the Tavoy district are the Hermyingyi, Widnes, Kanbauk, Taungpila and Kalonta. In the Hermyingyi mine (IV, Dunn, 1938), about 60 veins are worked. They range from 10 inches to 5 feet in width and from 500 to 1,100 feet in length. The tungstic oxide to tin oxide ratio (WO_3: SnO_2) is 2:1. The largest mine in the Yamethin district is the Mawchi mine in Karenni where 27 tin-tungsten veins are worked (idem. 1938).

China. Most of Chinese tungsten is won from placer deposits of scheelite and wolframite, although it is probable that of recent years some has come from lode deposits. Previous to the present war Chinese material could be mined, shipped and sold in European and American ports far below the price of domestic ores. The cost of producing tungsten from the Chinese deposits is very low. Lilley (I, 1936, p. 430) thinks that the reason is not due solely to the low cost of labour, but also the quality and extent of the deposits. The Chinese production comes from the provinces of Southern Kiangsi, northern Kwangtung, south-easterly Hunan and north-easterly Kwangsi, all in the south-easterly part of China. Since 1933 the world supply and price have to some extent been controlled by a Chinese organization formed in that year, "The Kwangtung Provincial Government Monopoly Bureau of Wolfram Ore."

Indo China. Indo China, ranking seventh in world production in 1938, accounts for the largest production from French territory.

In general, the tungsten, chiefly wolframite intimately associated with cassiterite, is obtained as a by-product from tin-bearing alluvials.

Malay States. The Malay States, ranking seventh in world production of tungsten during 1938, produces scheelite concentrates from lode deposits. Most of this was mined from a scheelite-fluorite ore-body at the Krannat Pulai mine near Ipoh in the Federated Malay States and some from mines in the State of Trenganni, the Unfederated Malay States.

Thailand (Siam). The production from Thailand (Siam) is chiefly in the form of wolframite concentrates.

AUSTRALASIA

Australia, Tasmania, New Zealand. Small deposits of tungsten minerals are widespread in Australia, Tasmania and New Zealand. The production appears to have been made chiefly from lode deposits of scheelite.

EUROPE

Cornwall, England. Wolframite and some scheelite, associated with cassiterite, occur in the tin lodes of Cornwall. The deposits of tungsten are not extensive.

Portugal. Portugal is the most important producer in Europe and ranked third in world production of tungsten in 1938. This output was mined from deposits of tungsten minerals in association with tin minerals in lode and alluvial deposits in the province of Beira Baixa between the Duro and Tagus Rivers. The tungsten minerals are mainly wolframite and huebnerite, which occur chiefly in quartz veins that cut granites and schists.

U.S.S.R. The production of tungsten from Russia in the past has been negligible. However, the repeated accounts of new finds, appearing in abstracts of the recent Russian literature, suggests the possibility of increased production. The writer has reference to quartz-wolframite veins in the Transbaikalia region (IV, Fiveg and Dorfman, 1938), to tin and tungsten deposits in the Amur basin (IV, Baturin and Krasnyi, 1937), to quartz-scheelite veins near Sverdlovsk in the Urals

(IV, Kolodkin, 1937), to quartz-wolframite veins in the Kazakstan steppes north of Lake Balkash (IV, Nakovnik, 1937), to high-temperature replacement (pyrometasomatic) deposits of scheelite and cassiterite in the Zeravshan Range (IV, Magakyan, 1937), to occurrences, reported to be of economic value, of scheelite in garnet zones in the Minusinsk basin in the Karysch region (IV, Speit, 1934) and to the "Third Year of Five Year Plan" tungsten deposit in the Chelyabinsk region of the Urals (IV, Kolodkin, 1936).

UNITED STATES

In 1938 the United States ranked fourth in world production of tungsten, but in 1939 it rose to third place.

Production by states in 1939 is given in Table V. Geological data concerning several tungsten properties in the United States are given in Table VI.

TABLE V - United States production by states in 1939[1]

State	Production in short tons	Equivalent per cent. of WO_3 content in quoted figures.
Nevada	2091	60
California	1250	60.63
Colorado	617	46.59
Idaho	226	66
Washington	56 165	65 14
Arizona	88	68
Montana	20	68.2
Utah	3	88

[1] Data compiled from "Molybdenum, Tungsten and Vanadium," Pre-print, Minerals Yearbook, U.S. Bureau of Mines, 1940, pp. 10-12.

TABLE VI - SUMMARISED GEOLOGIC DATA ON SEVERAL TUNGSTEN PROPERTIES IN THE UNITED STATES

(Listed in order of production by States)

Property or Mining Company	Tungsten-bearing Mineral	Type of Deposit	References (for complete titles see bibliography at end of report).
NEVADA Nevada Massachusetts Co., near Mill City.	Scheelite	Calcic-silicate zones known as "ore-beds," usually 5 feet wide by several hundred feet long.	V, Kerr, 1934, p. 21.
Silver Dyke Mine, Mina.	Scheelite	Lenses of scheelite in quartz veins.	U.S. Bur. Mines, Inf. Circ. 6852.
CALIFORNIA Atolia Mining Co., Atolia.	Scheelite	Series of veins in zone of shearing; ore widths usually less than 1 foot, occasionally 5 feet. Ore shoots up to 1100 feet long and one to 700 feet deep.	V, Hulin (1925, pp. 70-78).
Round Valley, Bishop	Scheelite	Calcic-silicate zone ("tactite")	V, Hess and Larsen (1921 pp. 273-274).
Pine Creek Tungsten Mine near Bishop.	Scheelite	With sulphides in calcic-silicate zone, ("tactite").	V, Hess and Larsen (1921 p. 274).

Bishop Tungsten Co., near Bishop.	Scheelite	With magnetite in calcic-silicate zone.	Cal. Journ. Min. and Geol., Oct. 1938, p. 403.
El Diablo Mining Co., near Bishop	Scheelite	In calcic-silicate zone	idem. p. 464.
COLORADO Cold Springs Mine, near Nederland.	Ferberite	Ferberite lenses along vein-fissures, lenses 80 feet by 9 inches.	U.S. Bur. Mines. Inf. Circ. 6852; Hess and Schaller, 1914.
Conger Mine, near Nederland.	Ferberite		I, Hess,Schaller, 1914.
IDAHO Ima Mine	Huebnerite	Huebnerite associated with sulphides.	U.S. Bur. Mines, Mines Yearbook, 1940, pp. 627-628.
WASHINGTON Germania Mine, Stevens county.	Wolframite	Lenticular deposits of wolframite in quartz veins with fluorite and tourmaline. Vein averages 2 feet wide.	V, Bancroft,1914, p.29; I, Lovering,1933, p.667.
MONTANA Jardine Mine, Park county.	Wolframite	Wolframite and arsenopyrite in quartz veins that cut pre-cambrian schists.	I, Lovering,1933, p.667.

CANADA (Excepting British Columbia).

In Canada, occurrences of tungsten minerals have been reported from Nova Scotia, New Brunswick, Quebec, Ontario, Northwest Territories, the Yukon and British Columbia. The greatest number of occurrences are in Nova Scotia and British Columbia; what appears to be the only production in Canada has also come from these Provinces.

Nova Scotia. Tungsten occurs in small amounts at many places along the south-easterly coast of Nova Scotia. The deposits are found in quartz veins that are mineralogically and structurally similar to the gold veins of the same region (VI, Newhouse, 1936, p. 827). In general, the quartz veins of this region are bedded with strongly folded Cambrian slates and quartzites which have been intruded by Silurian granitic rocks (I, Lindgren, 1933, pp. 561-562). The tungsten mineralization appears to have been concentrated along the crests and troughs of steeply pitching folds.

In 1931, Messervey (VI, 1931, p. 30) summarized the geographic distribution of tungsten minerals in the Province as follows: Halifax county, Moose River, Waverly and Oldham; Lunenburg county, Indian Path and New Ross; Queens county, Fifteen Mile Branch and Molega. In 1939, the only active properties, as noted by the Dominion Bureau of Statistics (III, 1940, pp. 29-32) appear to have been the following places: Moose River district, North Waverly and Lake Charlotte, all in Halifax county, and from near Lunenburg, Lunenburg county.

Of these, the Moose River area is the most important, and contains the property of the former Scheelite Mines, Limited, near Stillwater Brook, the most notable mine; some scheelite has been found, however, in the workings of the adjacent Moose River mines. The Stillwater Brook deposit (VI, Camsell, 1916, pp. 243-250) consists of three veins ranging from 1 inch to 8 inches in thickness, that occur bedded in folded quartzites and slates. The scheelite is found in disconnected lenses 2 to 6 inches in width and from 6 inches to 2 feet in length that are mainly at the apex of an anticline or in the trough of a syncline. The vein mineralization consists of scheelite, quartz, arsenopyrite, white mica, feldspar, tourmaline and ankeritic carbonate. The property has been developed by about 5,800 feet of underground workings (Messervey, 1931, p. 25). In 1911 the operating company built a concentrator with a capacity of 30 tons per twenty-four hours. During the years the mill was in operation, 1912 and 1913, 25 tons of concen-

trates was recovered (VI, Camsell, 1916, p. 250).

The only recent shipment of tungsten concentrates from Nova Scotia is one made early in 1940 by the Kirkpatrick Tungsten Syndicate (III, Dominion Bur. Statistics, 1940, p. 30) from their property at Goff, Halifax county; this property is presumably the one near Stillwater Brook in the Moose River area.

New Brunswick. In New Brunswick, tungsten occurs at Burnt Hill, in York county. The deposit (VI, Camsell, 1916, p. 248) consists of a wolframite-bearing quartz vein, in argillites that are cut by granite about three-quarters of a mile distant. The main vein ranges from 24 to 32 inches in width. The development work, as of 1917, consists of an 150-foot shaft, short adits and surface workings. An all-gravity concentrator was built on this property in 1916 and, in 1917 the mill was treating about 15 tons of ore per day, averaging 1 per cent. or less tungstic oxide (WO_3) (VI, Gwillim, 1917, p. 197). The only production from this property appears to have been 11 tons of concentrates obtained in 1918 (III, Dom. Bur. Statistics, 1939, p. 30).

Quebec. In Quebec, scheelite has been reported (VI, Walker, 1909, p. 31) as a minor constituent in some galena-sphalerite-chalcopyrite-pyrrhotite veins from Beauce county. Little development work has been done on this discovery. In 1939 a tungsten-bearing deposit near Guigues in the Lake Temiskaming area, was prospected (III, Dom. Bur. Statistics, 1940, p. 30).

Ontario. In Ontario, scheelite, apparently only of mineralogical interest, has been found in the Sudbury district at the Victoria mines of the old Mona Nickel Company (VI, Walker, 1909, p. 33). Float of wolframite has been reported from the Lake Couchiching area (idem. p. 34).

Manitoba. In eastern Manitoba scheelite was found near Falcon Lake in 1918 and some development work done during that year (III, Dom. Bur. Statistics, 1940, p. 30). The deposit consists of scheelite in lenticular replacement zones or veins within schists that are adjacent to large areas of granitic rocks (VI, DeLury, 1918, pp. 186-188); ore is reported (idem. p. 188) to occur in a zone measuring from 3 to 5 feet wide.

Northwest Territories. In the Northwest Territories tungsten has been found at Outpost Islands in Great Slave Lake and in the vicinity of Gilmour Lake.

The Great Slave Lake occurrence (VI, Hawley, 1939, pp. 53 to 67) consists of mineralized shear-zones in micaceous quartzites. The mineralization consists of ferberite (iron tungstate) associated with magnetite, specular hematite, probably ilmenite, pyrite. marcasite, bornite, chalcocite, covellite, molybdenite, powellite, chlorite, sericite and gold; an unknown tin mineral, possibly cassiterite is reported to be present (idem. 1939, pp. 54-55).

The Gilmour Lake occurrence is reported in the Northern Miner for October 1940. p. 17, by A. W. Jolliffe of the Geological Survey to consist of scheelite in quartz-calcite stringers and lenses which follow bedding planes in greywacke sediments. The scheelite-bearing veins range up to 30 inches in width and may be traced with certainty for more than 20 feet; although high tungsten values have been found, the size of the ore bodies is unknown. The mineral association consists of scheelite, gold, pyrrhotite, arsenopyrite, pyrite, sphalerite, quartz calcite and other minerals. Up to October, 1940, only a small amount of development had been done.

During the summer of 1940, prospectors made several discoveries of scheelite within the general Gilmour Lake area.

Yukon. In some of the Yukon placer areas small amounts of placer scheelite have been found and in 1917 a small shipment of scheelite was made from Dublin Gulch in the Mayo district. Cairnes (VI, 1916, p. 17) mentions the occurrence of wolframite and cassiterite with the scheelite. The only lode scheelite reported in the area consisted of small amounts of scheelite in quartz stringers that occur in pegmatitic zones within the granite.

CHAPTER III

DESCRIPTION OF BRITISH COLUMBIA TUNGSTEN DEPOSITS.

In common with the Western United States, British Columbia is part of that geologic unit known as the Cordilleran region which extends north-westerly and south-easterly along the westerly part of North America. The deposits responsible for the United States production of tungsten lie within this region, and it is therefore not unreasonable to expect somewhat comparable deposits in the part of the same region which form British Columbia. For geologic reasons, therefore, as well as economic, further prospecting for tungsten minerals within British Columbia and the development of likely prospects should be encouraged.

ALICE ARM AREA.

In this area scheelite has been reported from the Esperanza, a silver property at latitude north 55 degrees 30 minutes and longitude west 129 degrees 30 minutes, about a mile north of Alice Arm. Clothier (VII, 1924, p. 53) reports finding samples of scheelite on the dump and Hanson (VII, 1930, p. 64) in describing the mineralogy of the veins says: "Scheelite is also reported."

TERRACE AREA.

The Terrace area is in northern British Columbia and centres around Terrace, a small town on the Canadian National Railway, 94.6 miles east of Prince Rupert. It may be reached from Vancouver either by steamer to Prince Rupert and thence by train easterly, or by Canadian National Railway northerly to Jasper Park and thence westerly, or by motor-road from Vancouver to Prince George and then westerly.

THORNHILL MT. Scheelite has been reported from the St. Paul, latitude north 54 degrees, 29 minutes longitude west 128 degrees 25 minutes, in the Ptarmigan group on Thornhill Mt. (VII, Hanson, 1925, pp. 110 to 118; VII, Marshall, 1926, pp. 39 to 41; VII, Mandy, 1930, p. 78; VII, Kindle, 1937, p. 9). This group is owned by J.A. and A. Michaud of Terrace. The writer did not examine the property and the following information has been abstracted from the above reports.

The Ptarmigan group is on the summit and east slope of Thornhill mountain and about 7 miles in an air-line south-easterly from Terrace.

This property has been prospected chiefly for gold and silver, the work consisting mostly of open-cuts and adits on veins other than the scheelite vein.

The property may be reached by following the Terrace-Lakelse Lake motor-road for 8 miles from Terrace, then by a steep trail 3 miles long to the Forest Branch lookout on top of Thornhill mountain.

The Thornhill mountain area lies within the main Coast Range batholith and approximately 18 miles from its north-easterly margin. The batholith in this latitude is about 88 miles wide as measured between sockeye, 17 miles easterly from Prince Rupert on the coast and Doreen on the Skeena River, 126 miles easterly from Prince Rupert. It is to be noted that the country south-west of Thornhill mountain is marked by fairly continuous areas of granitic rocks, but towards the north-east within areas of bedded volcanic and sedimentary rocks they outcrop to a lesser extent (see Fig. I on p. 430 of Kerr, VII, 1938). The scheelite occurrences on Thornhill mountain, therefore, are relatively close to the eastern margin of the main batholith.

The occurrence consists of a quartz-scheelite vein, 6 inches to 2 feet wide, that has been traced for 200 feet. The vein is described by Hanson (VII, 1925, p. 118) as follows:

> "This is a pegmatitic quartz vein mineralized with pyrite, chalcopyrite, galena, sphalerite, free gold and scheelite, in a gangue of quartz, barite and feldspar. The scheelite is sporadically distributed through the vein in fairly large nodules as much as 3 inches in diameter and makes exceptionally fine specimens."

The rock on the property is chiefly grandiorite but granite and porphyritic granite and late aplite dykes also occur. Large inclusions of schistose rocks lie within the granodiorite.

Exploration apparently exposed the vein for a length of 200 feet; no underground work has been done.

HAZELTON AREA

The Hazelton area centres around Hazelton, a village on the Skeena River in Northern British Columbia, about 126 miles in an air-line north-easterly from the city of Prince Rupert on the Pacific coast. Hazelton is reached either by way of Highway Routes Nos. 1 to 2 to 16 northerly from Vancouver, a distance of 830 miles, or by way of the Canadian National Railway from Price Rupert easterly to New Hazelton a distance of 80.6 miles by rail and 2 miles by road; regular steamer service connects Prince Rupert with Vancouver.

The tungsten properties in the Hazelton area, the Red Rose and Black Prince, are on the west and east sides respectively of Rocher Déboulé Range. This range, 15 miles long in a north-south direction and 5 miles wide, extends southerly from Hazelton between the Skeena and Bulkley Rivers.

The tungsten deposits lie on either side of a grandiorite mass that forms the core of the Rocher Déboulé Range. This range lies approximately 32 miles north-easterly from the easterly contact of the main Coast Range batholith at Doreen on the Skeena River 51 miles south-westerly from Hazelton. The rocks between the Coast Range batholith and the Rocher Déboulé intrusive are mainly sediments of which argillites and quartzites are the common types. Descriptions of the regional geology have been given by Hanson (VII, 1924, pp. 38-43) and Kerr (VII, 1936, pp. 69-70; 1938; pp. 1431-1440).

RED ROSE

This property consists of the mineral claims Tungsten Nos. 1 to 8, inclusive, owned by Mrs. Barbara S. Sargent, New Hazelton P.O. The property at latitude north 55 degrees 7 minutes, longitude west 127 degrees 38 minutes, is on the west side of the Rocher Déboulé Range south of Hazelton, and the workings are between elevations of 5,200 and 6,360 feet on the divide between Red Rose (Balsam) and Armagosa Creeks, westerly-flowing tributaries of Juniper Creek (see Map No. 3 D, Department of Lands, British Columbia, 1937). Juniper Creek flows south-westerly into the Skeena River at Skeena Crossing, approximately 15 miles down-stream from Hazelton.

The Red Rose property was first staked and owned by Messrs. C. Peterson and C. Ek, and preliminary work was done about 1914 (Galloway, VII, 1914, P. 190: 1916, p. 113). Prior to 1923, only the gold-silver showings were explored, the existence of tungsten on the property being unknown. Kindle (VII, 1940, p. 56) mentions this work as follows:

"The original group of five claims, staked by C. Peterson and C. Ek about 1913, were named as follows: Red Rose, Yellowhammer, Prosperity, Juniper, and Summit. In 1914, a syndicate headed by T. J. Vaughan-Rhys secured an option and drove two adit drifts at elevations of 5,450 and 5,690 feet on a sheared that contains a little gold and copper. At elevation 5,150 feet a crosscut adit was driven 430 feet to intercept the downward continuation of the sheared zone, but without success. In 1916 the Skeena Development Company continued the work, driving the adit at elevation 5,450 feet a total distance of 250 feet, and the upper adit a total distance of 160 feet along the sheared zone."

About 1923, tungsten-bearing minerals were recognized in a quartz vein that outcropped on a shoulder 700 feet above the uppermost gold-silver workings. This tungsten discovery was first reported upon by Galloway (VII, 1923, p. 106) and a further description of the occurrence is given by Hurst (VII, 1924, pp. 44-45). It is understood that since the discovery of tungsten little work, other than assessment, was done until the summer of 1940 when the Consolidated Mining and Smelting Company, Limited, optionees, commenced diamond-drilling; this was started after the writer's visit to the property in July, 1939.

The writer has been unable to find any records of production from the property.

In addition to the reports mentioned above, the property has been described by O'Neill (VII, 1919, pp. 18-19); Lay (VII, 1926, p. 126 and Hurst, VII, 1927, pp. 49-50).

The property is reached by motor-road from Hazelton to Skeena Crossing, a distance of 15 miles, thence by a poor road up Juniper Creek for 5.1 miles to the former site of the now inactive Rocher Déboulé mine power-house. From this point the road, passable only by wagon, follows up Juniper Creek for 2 1/2 miles to the Red Rose trail. The lowermost workings, elevation 5,200 feet, are approximately 3 miles up this trail, which, at the time of examination, was being repaired so that a diamond-drill rig could be taken over it on a go-devil.

The mountain-side in the vicinity of the workings extends between 1,000 and 2,200 feet above timberline. Slope angles reach 35 degrees or more, and are characterised by alternating rock-bluffs and talus-slides.

The details of the local geology as interpreted by the present writer are given in (Fig. 3).

The rocks consist of sediments, now mostly hornfels, that have been intruded by sill-like masses of diorite and diorite-porphyry. These rocks strike north-easterly at right angles and towards a large mass of grandiorite, the westerly contact of which lies about 750 feet east of the tungsten showings. The youngest rock noticed was a small dyke of feldspar porphyry intrusive into the grandiorite.

In the vicinity of the workings the sediments are chiefly dense, massive hornfels rocks with 1-inch shaly partings spaced from 6 inches to 2 feet apart. The rocks weather to light-brown, but fresh surfaces are grey, or brownish, as a result of the presence of fine biotite flakes. Well-defined sedimentary banding is lacking and determinations of attitudes have to be made where shaly partings are sufficiently well developed.

Approximately 2,000 feet and beyond to the west, the sediments are still fine-grained, but are definitely more argillaceous, blacker in colour and less massive. The brownish cast on the fresh surfaces is absent. This change is the result of the gradual disappearance of biotite farther away from the grandiorite where the contact metamorphic effects become less pronounced. These rocks are probably argillaceous tuffs.

The diorite and diorite-porphyry are dark grey to greenish weathering rocks, grey to black-white on the fresh surface and massive in structure. Texturally the diorite is fine-grained granitic, most of the grains being approximately 0.5 mm. in diameter. The diorite-porphyry consists of well-shaped plagioclase-feldspar crystals averaging 1 by 2 mm. set in a fine-grained to dense groundmass.

The grandiorite is a massive, light-grey rock and much lighter in colour than any of the other rocks. Although it is fairly even-grained in texture, the grain-sizes range from 2 to 10 mm. in average diameters.

From the few strikes and dips obtainable the writer concludes that the rocks in the vicinity of the Red Rose workings strike in a general north-easterly direction and dip north-westward. Bedded rocks in bluffs half a mile southerly across Red Rose Creek strike north 35 degrees east and are approximately vertical. The north-westward dip of the sediments in the vicinity of the Red Rose workings, a definite north-westward dip of 35 degrees was observed in the No. 2 adit, is at variance with the

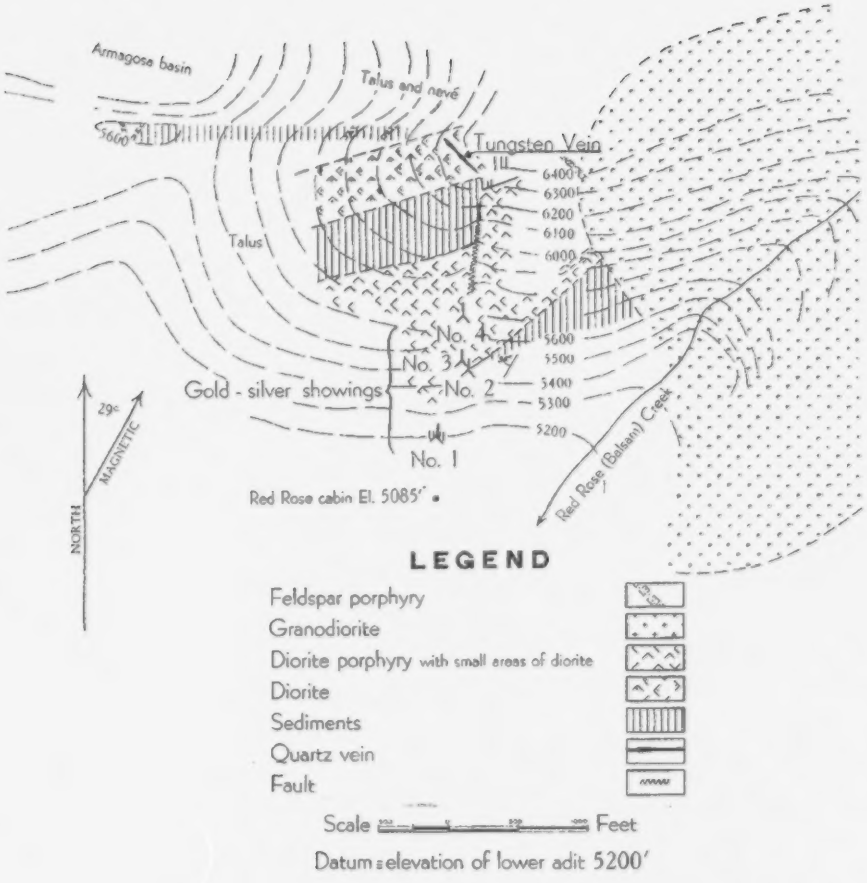

Fig. 3. Red Rose. Plan showing surface workings and local geology. Barometer, pace and compass survey.

general south-eastward dip for the sediments in the Juniper Creek basin as given by O'Neill on the areal map (VII, 1919, Map No. 1731) accompanying his memoir. This variance may be explained by a slight roll or small fold superimposed on the major south-eastward dipping structure.

The major structural features in the vicinity of the workings are a diorite sill about 400 feet thick, and a diorite-porphyry sill about 800 feet thick. These sills strike north-easterly and dip north-westward. The smaller one appears to have had a localizing influence on the main tungsten mineralization.

The mineral showings on the Red Rose property are described under two headings: first, the old Red Rose vein that contains gold-silver and copper on which work prior to 1923 was done, and second, a description of the tungsten occurrences above but on the same hillside. The present work is being done on the tungsten showings. Inasmuch as the present examination was made as part of a general tungsten survey, the gold-silver and copper veins will be referred to only insofar as they have geological bearing on those containing tungsten.

The most recent report on the old workings is by Kindle (VII, 1940, p. 57), who describes them as follows:

> "The No. 1 cross-cut adit, driven 430 feet north at elevation 5,150 feet, is entirely in sediments.
>
> The sheared zone on which most of the early work was done outcrops at intervals up a steep ravine (slope of 34 degrees) between elevations of 5,425 and 5,825 feet. It strikes from north 30 to north 45 degrees west and dips 45 degrees southwest. In the No. 3 adit, at elevation 5,450 feet the sheared zone ranges from 1 to 4 feet in width. It consists of soft, rusty, pulverized rock largely leached of its sulphide content. An 18-inch channel sample taken across this material, 65 feet from the face of the adit, assayed: gold, 0.015 ounce a ton; silver, 0.09 ounce a ton; tungsten, none. In the No. 4 adit at elevation 5,690 feet the sheared zone is also composed largely of soft, ground-up, rusty, altered rock and has an average width of 3 feet. For 70 feet from the portal the sheared zone is in sediments, but from 70 feet to the face of the drift the hanging-wall is diorite. Along the part of the drift in the sediments the sheared zone is replaced by considerable vein

quartz that carries a little pyrite. A channel sample taken across the vein 50 feet from the portal, where there is a 24-inch width of vein quartz containing 3 per cent. of pyrite, assayed: gold, 0.54 ounce a ton; silver, 0.79 ounce a ton; tungsten, none.

No. 2 adit is 100 feet southeast of and 35 feet below the No. 3 adit. It is driven 50 feet along a vein that lies parallel to the main sheared zone. This vein ranges from 6 to 24 inches in width, and has been traced less than 100 feet. The hanging-wall is diorite and the foot-wall is altered argillite. The vein consists of the following gangue minerals, in order of abundance, hornblende, quartz and biotite, and carries a little pyrrhotite, arsenopyrite and chalcopyrite."

The tungsten occurs in a vein that outcrops on the hillside as shown in (Fig. 3). The vein strikes north 45 degrees west, dips from 55 degrees to 60 degrees south-westward and ranges in width from 18 inches to 8 feet. The exposures, three in number, indicate a strike length of 290 feet and a third reported exposure, covered by snow and ice at the time of the writer's visit, would extend this length to 330 feet. The vein-matter consists of quartz, apatite, scheelite and ferberite with very small amounts of chalcopyrite and molybdenite.

This tungsten vein is in part a siliceous replacement, along a shear-zone, by murky, grey quartz, and in part a filling of later fractures by veinlets and lenticular areas of white, milky quartz. The milky quartz is the more abundant of the two types of silicification. The extreme width and rather indefinite walls of the vein towards the northwest end of the outcrop is perhaps explained by a gradual silicification of the wall-rock from the central fracture. It is to be noted that most of the later mineralization appears to be confined to the white milky quartz.

Chalcopyrite occurs as scattered grains within milky quartz, and molybdenite as occasional, 1/4-inch sulphide-filled fractures that extend for a length of only a few inches within the quartz.

Orthoclase feldspar and scheelite,(see Plate 1-A) both nearly colourless, and ferberite, dark brown in colour, not only occur abundantly as clusters either together or separately within the milky quartz, but also in small amounts in the grey replacement quartz. In the most south-easterly

exposure scheelite and ferberite occur together in patches ranging from 1/4-inch to 2 inches in diameter. In the most north-westerly exposure the minerals are found separately, the ferberite as irregularly scattered small blades and the scheelite as an indefinite streak of 1/2-inch crystals, the streak ranging from 1/2-inch to 2 inches and traceable for 3 feet before dying out in vein-quartz. Elsewhere, the scheelite, of more widespread distribution than the ferberite, is seen as small grains not readily distinguishable without the aid of ultra-violet light.

Relationship Between the Tungsten Vein and the Old Red Rose Vein.

Whether the tungsten vein and the gold-silver vein of the old workings are one, cannot be proved definitely. Talus between the ends of the two obscures any possible outcrop connexion between them. However, certain features indicate that they may be the same vein. The projected strike of either vein on the hillside approximates the position of the other, but they differ mineralogically. The tungsten vein contains scheelite, ferberite, a little molybdenite and chalcopyrite. The gold-silver vein, a small amount of scheelite, chalcopyrite and safflorite. It may be noted, however, that there appears to be a decrease in the sulphide content of the gold-silver vein up the hill, and the upper part is all quartz and lacking in sulphides. Although there has been a change in mineralogy between the gold-silver showings and the tungsten showings, the minerals in both belong to a group of minerals that characteristically form within the same high temperature range. Therefore, though not definitely proved, it is probable that the tungsten vein is a continuation of the gold-silver vein.

Faulting appears to have occurred along the site of the gold-silver vein. This vein is a mineralized shear-zone that outcrops on the hillside between elevations of 5,750 and 6,100 feet (see Fig. 3), strikes north-westerly and dips approximately 45 degrees south-westward. The shear-zone is marked by well-defined faults for a distance of approximately 500 feet northerly from Number 4 adit (see Fig. 3) and then by a quartz lens, ranging from 1 foot to 5 feet in width and extending from an elevation of 6,100 feet to 6,225 feet. Faulting along this shear appears to have displaced the rocks on either side of it. A specific indication of the amount of the displacement may be seen in the uphill contact of the lower diorite-porphyry sill. The north-easterly extension of the contact has been faulted approximately 400 feet nor-

therly on the slope of the hill. Extensive talus prevents continuous tracing of contacts, but mapping of the rock types on either side of the shear also indicate a northerly displacement of the rocks on the east side of the shear. When this displacement is considered with the north-westerly strike and the south-westerly dip of the fault, it is seen that such a displacement could be caused by a normal fault.

The quartz-sulphide mineralization of the old Red Rose working apparently follows the shear. Judging from the indicated replacement of sheared rock by the quartz in the lens that outcrops between elevations of 6,190 and 6,225 feet, major movements along the shear are considered to have antedated vein-formation.

The tungsten vein is exposed in five and possibly six surface workings which will be described from the south-east to the north-west along the strike of the vein.

Number 1 working, at an elevation of 6,350 feet, is an open-cut that has been driven north 30 degrees west for 12 feet to a 5-foot face. The cut was badly sloughed, but at the top of the face an 18-inch width of vein-quartz was seen. A study of the vein-matter in the dump indicated the presence of a considerable amount of scheelite and ferberite, the scheelite being slightly more abundant. A selected sample of mineralized fragments from the dump assayed: Tungstic oxide (WO_3), 22.2 per cent.

Number 2 working, at an elevation of 6,360 feet and 27 feet north 60 degrees west from Number 1, is a small trench in dirt and talus, no vein-matter is exposed.

Number 3 working, at an elevation of 6,350 feet and 45 feet north 75 degrees west from Number 2, is also a small dirt cut with no vein-matter exposed.

Number 4 working, at an elevation of 6,350 feet and 50 feet north 20 degrees west from Number 3, is an open-cut that has been driven north 60 degrees east for 12 feet. This cut exposes a vein-width of 8 feet. No mineralization other than quartz was seen in the vein-matter.

Beginning at a point, elevation 6,350 feet and 125 feet north 45 degrees west from Number 4 working, the vein is continuously exposed by a rib-like outcrop for 45 feet in a direction north 40 degrees west to an elevation of 6,330 feet. The vein-matter ranges from 6 to 10 feet in width,

and consists of quartz with small amounts of chalcopyrite, ferberite and scheelite. A few scattered blades of ferberite only were seen at the south-east end of this outcrop. Scheelite was observed only at the north-west end of the outcrop, where it occurred as an indefinite streak of 1/2-inch crystals in solid vein-matter lying close to and paralleling the footwall of the vein. This streak ranged from 1/2-inch to 2 inches in width and could be traced for approximately 3 feet before dying out in vein-quartz; associated fissuring was absent.

Number 5 working, the last to the north-west, is at an elevation of 6,310 feet and 45 feet north 30 degrees west from the north-west end of the outcrop described above. This working was filled with snow and ice at the time of the writer's visit, but it evidently is an open-cut that has been driven south-easterly, presumably along the vein.

BLACK PRINCE

This property consists of the mineral claims Cariboo and Black Bear, owned by Mrs. Barbara S. Sargent of New Hazelton.

The property, latitude north 55 degrees 10 minutes and longitude west 127 degrees 36 minutes, is on the east side of Rocher Déboulé Mountain between elevations 4,650 and 5,020 feet at the headwaters of Mudflat Creek, a northeasterly-flowing tributary of the Bulkley River, (see Map No. 3D, Department of Lands, British Columbia, 1937). Mudflat Creek joins the Bulkley River approximately 1 mile above the mouth of the Suskwa River; the road-crossing of the creek is approximately 6 miles south-easterly from New Hazelton.

Most of the present surface work on the tungsten showings appears to have been done before 1916, as described by Galloway (VII, 1916, p. 118) under the name of Black Diamond. Other than possibly extending the open-cuts a few feet, very little development appears to have been done since that time.

The writer can find no record of production from the property.

The property is reached by following the motor-road for 9.2 miles south-easterly from New Hazelton to a wood-road that turns off to the west. This road may be followed by motor for half a mile and then by foot for approximately 1 mile. From there a pack-horse trail branches to the north-west and leads to an abandoned camp-cabin 6 miles distant and at an elevation of 4,150 feet. For the first 5 miles this trail was in good condition, but the last mile was covered by heavy windfalls

and thick brush so that progress even on foot was very difficult.

The mountain-side in the vicinity of the workings is steep and consists mostly of bare rock and talus-slopes that form the south-easterly wall of a large cirque, now occupied by two cirque-lakes, one in a northerly direction 1,000 feet below the workings, and the other in a north-westerly direction, 400 feet below the workings. Water from small glaciers a few hundred feet above, flow into the upper lake and from thence cascades into the lower lake about 600 feet below.

A small cabin, now in disrepair, stands on the edge of a small sod-swamp that lies between the two cirque-lakes.

The showings are in a mineralized shear-zone in granite that forms the easterly margin of the Rocher Déboulé intrusive mass. Sedimentary rocks lie approximately 1,500 feet to the north-east and extend in that direction for several miles down Mudflat Creek and across the Bulkley River; in the vicinity of the Black Prince the grandiorite-sedimentary contact trends northerly. The relation of the Rocher Déboulé intrusive mass to the main east batholith has already been given on pages 66-67.

The tungsten-bearing shear-zone strikes north 35 degrees west, dips from 60 to 72 degrees south-westward and ranges from 18 inches to 2 feet in width. The workings seen by the writer indicate an exposed horizontal length of 80 feet, through a vertical distance of 70 feet, between elevations of 4,950 and 5,020 feet. However, the shear continues north-westerly and south-easterly beyond the extremities of the exposed section. North-westerly, the presence of the shear has been noted by Kindle (VII, 1940, p. 47) at an elevation of 4,650 feet in a cut inaccessible to the present writer. For 500 feet south-easterly beyond the last open-cut the shear may be seen extending up the face of a rock bluff towards the mountain-top. It appears only as a streak of rust in this bluff and probably contains little vein-matter. This indicates a probably horizontal length of the shear, though not necessarily of the vein-matter, of approximately 900 feet through a vertical distance of approximately 600 feet.

The quartz lenses in a shear-zone enclosed in sheared granite are from one to three in number, are generally continuous and range from 6 to 14 inches in width. These lenses contain abundant limonite and small amounts of unoxidized pyrite, molybdenite, ferberite and scheelite. Thin streaks

of feldspar crystals and bleached mica flakes also occur in the vein-matter.

Scheelite and ferberite are found as discrete grains in about equal amounts within quartz vein-matter on the dump from an open-cut, elevation of 5,020 feet; none was recognized elsewhere. The scheelite is widely scattered throughout this material as grains averaging 1/16th of an inch in diameter and more rarely as well-shaped crystals measuring about 1/8-inch to 1/4-inch. The ferberite, less widely scattered than the scheelite, occurs in crystals up to 1/4-inch in size. Larger crystals and grains of ferberite have been described in earlier reports, but most of this material appears to have disappeared.

Extreme weathering and oxidation of the exposures is marked. Abundant snow and ice water having relatively easy access to vein-matter plus an original abundance of sulphides along the shear-zone have caused the extreme weathering and oxidation of the sulphides. These processes have resulted in the development of cellular quartz and residual limonitic material left within the cell spaces. The writer believes that weathering, plus oxidation, have decreased the amount of scheelite and ferberite at present visible in the vein-exposures. The existence of more scheelite in the vein-matter before oxidation is suggested by the fact that the unoxidized material carries a larger percentage of the mineral.

Although it is improbable that scheelite would be destroyed by oxidation, a decrease, in the amount originally present in a surface showing, could be attributed to the turbulent and erosive action of the run-off water. This action would be particularly strong at this altitude and on such steep slopes.

The suggestion that more ferberite than is at present seen, existed in the vein-matter before oxidation, is warranted for two reasons: (1) the writer observed small residual fragments of ferberite embedded in crystal-shaped casts of limonite, (2) although ferberite and all other minerals of the wolframite series are commonly considered refractory, its alteration to iron oxide, has been noted by several writers. For a discussion of the oxidation of tungsten minerals (see I, Emmons, 1917, pp. 427-432).

In view of these arguments in favour of the former existence of scheelite and ferberite in now oxidized vein-matter, the writer suggests that an estimate of the tungsten content of the vein can be made only in fresh, unoxidized vein-matter.

To obtain this it is necessary to extend the present workings to points below the zone of destructively strong oxidation.

The workings, 500 feet above timber-line, extend up a slide- or talus-filled draw, up the rock bluffs that feed the draw and on to a grassy, partly heather-covered shoulder.

A description of this exploration will begin at the lowest showing on the vein-shear accessible to the writer in July.

Number 1, at an elevation of 4,953 feet, is a small stripping on a 60-degree face, 4 feet high, that exposes a 14-inch width of shear, containing 12 inches of leached quartz mineralized with a little pyrite and molybdenite. Kindle (VII, 1940, p. 47) describes an exposure on the vein at an elevation of 4,650 feet. The guide, John Sargent, advised the writer that the lowermost showing, probably that seen by Kindle at 4,650 feet, was formerly accessible by ladders running across the face of the bluff.

Number 2, 30 feet vertically above and south 35 degrees east from Number 1, is an open-cut that has been driven south 35 degrees east for 15 feet to an 8-foot face. The face exposes a footwall- and hangingwall-shear. The footwall-shear is 8 inches wide at the floor but upwards and towards Number 3 working it dies out to 1 inch. The hangingwall-shear, 20 inches wide, constitutes the main vein-shear, continuing upwards from Number 1 working and past Number 2 to Number 3 and beyond to the last exposure in Number 4. This shear consists of three quartz ribs, 1-inch, 2- and 3-inches wide within sheared and decomposed granite. Three other minor shears in the hanging-wall of this main shear are exposed by adjacent bluff-faces. These shears range from a knife-edge to 3 inches in width and consist of sheared rock and small amounts of relatively unmineralized quartz.

Number 3 working, at an elevation of 5,003 feet and south 35 degrees east from Number 2, is an open-cut that extends south 35 degrees east for 10 feet to the portal of an adit that is driven in the same direction for 10 feet to the face. This combined open-cut and adit is on the upward continuation of the main hangingwall-shear from Number 2 working. This shear is 18 inches wide and contains from 6 to 14 inches of quartz which is badly leached and the cavities partly filled with limonitic material. Some areas of the quartz contained decomposed crystals of feldspar and mica, and the texture suggested pegmatitic material. Small amounts of unoxidized pyrite and chalcopyrite still remain in the quartz.

Number 4 working, at an elevation of 5,020 feet and south 35 degrees east from Number 3, is an open-cut that has been driven south 35 degrees east for 16 feet. It is on the same main vein-shear that extends upwards from Number 1 through Numbers 2 and 3 workings. In Number 4 the shear is 2 feet wide at the face and consists of three lenses of cellular quartz, combining a footwall-lens 5 inches wide, a middle lens 6 inches wide and a hangingwall-lens 6 inches wide. With the exception of a few remnant grains of pyrite, ferberite and scheelite, the quartz contained patches of limonitic material only.

Three small pits have been dug on the shoulder of the mountain for a distance of 96 feet south-easterly from Number 4 working. These were completely caved at the time of the writer's visit. The dumps indicated that only a little quartz had been found in them.

This property was examined by the writer in July, 1940.

NORTH POINT OF FRASER RIVER AREA

The North Point of the Fraser River area is adjacent to the most northerly point or bend of the Fraser River at latitude north 54 degrees 7 minutes and longitude west 122 degrees 22 minutes. The main settlement in the area is Hansard, a station on the Canadian National Railway 46 miles east of Prince George. From Hansard travel is by way of private motor-boats or "kickers" on the river.

The Scheelite occurrences in the area were not examined by the writer but they have been fully described by Lay (VII, 1935, pp. C-30 to C-32) as follows:

> "In this region the formation consists of silicified schists, mainly quartz-muscovite schist, quartz-biotite schist, and quartz-sericite schist, in which occur a number of quartz veins. These veins are in most cases sparingly mineralized with pyrite and some contain in addition galena and sphalerite. They vary in width from a few inches up to several feet and have free walls. On the Ada claim, owned by the estate of the late Oscar Eden and developed by an adit and drift therefrom, one vein contains a noteworthy amount of scheelite. This mineral has also been found, although not to the same extent, in a vein on the Silver group occurring in similar formation, situated about 1 mile to the east on Averil creek.

Most of the veins exhibit evidence of post-mineral movement, and the two veins in which scheelite occurs also contain considerable amounts of graphite. In no other vein was graphite observed.

Good water transportation is available for quite large craft between the Canadian National Railway at "Hudson's Bay Spur," about 2 miles west of Hansard, and this property, a distance of about 24 miles. In view of this fact and because of the comparatively small expense involved, some additional development on the vein mentioned on the Ada seems justified to further test tungsten possibilities.

No commercial possibilities are apparent in so far as gold, silver, or lead contents are concerned.

Although these properties have been previously examined and an account appears in the 1928 Annual Report of the Minister of Mines, British Columbia, on pages 191 and 192, they were re-examined this year, in view of the interest evinced at the present time in tungsten properties, and also because additional work had been done in the interim on the Silver group.

Ada. This mineral claim, owned by the estate of the late Oscar Eden, is situated contiguous to the eastern boundary of Pre-emtpion Lot 9606, at the most northerly point and on the right bank of the Fraser river. Low-lying meadow-land flanks the right bank of the Fraser river, extending back for a distance of about 1,500 feet. From this point the valley-rim, covered with dense vegetation and heavily timbered, rises abruptly at an angle of about 40 degrees. The property is readily reached by motor-boat from Hansard, from which it is distant about 25 miles.

The formation consists of silicified quartz-muscovite schist which strikes north 57 degrees west and dips about 60 degrees south-west. Within this host-rock two quartz veins are exposed in the adit on the property. These conform on strike and dip with the planes of schistosity of the enclosing rocks and are from 3 1/2 to 4 feet in width. Mineralization consists of pyrite, galena, and scheelite. The last-mentioned mineral is exposed, as far as is known, in one vein and only in the underground workings.

The veins show evidence of intense post-mineral move-

ment and in one case the amount of graphite present is noteworthy. The schist formation gradually passes into an acid rock of granitic texture towards the face of the underground workings.

The property was originally staked or acquired by the late Oscar Eden, and in 1922 the North Point Mining Company, Limited, was incorporated for its development. This company carried out the underground development described below, and subsequently another company, called the Granite Mining Company, was incorporated for the purpose of operation. No work has, however, been done at this property for more than ten years. It seems evident that the gold-silver-lead possibilities were originally deemed worth investigating as tungsten was not exposed on the surface, nor its extent investigated when found underground.

Surface workings have now entirely caved, but consisted originally of a shallow shaft 15 feet in depth and a drift 30 feet in length. These workings were driven in a vein 5 feet in width composed of quartz, with pyrite and galena. In the 1922 Annual Report it is stated that this drift 'Shows the vein to be only slightly mineralized.' A sample taken in 1928 from a small dump of the most heavily mineralized pieces assayed: Gold, 0.04 oz. per ton; silver 4.2 per ton; lead. 10 per cent.

As determined by aneroid this year the elevation of the shaft is 310 feet above the river.

To explore the region below the above-mentioned vein an adit has been driven a total distance of 675 feet on a bearing north 48 degrees east at a depth of 210 feet below the collar of the shaft. Two veins were cut by the adit--one at 372 feet from the portal and the other at the face. Both veins conform in strike and dip with the enclosing quartz-muscovite schist, striking north 57 degrees west and dipping at about 60 degrees south-west. The former is quartz-filled, sparingly mineralized with pyrite, and 3 1/2 to 4 feet wide. To intercept its north-westward continuation a branch crosscut was run a distance of 65 feet on a bearing north 8 degrees east at a point 340 feet from the portal of the main adit, without results. The vein cut at the face of the main adit was followed by a drift for a distance of 33 feet south-east, and the width showing in the drift-face is 4 1/2 feet. The filling consists of intensely sheared material, quartz, scheelite and graphite. A sample taken across a width of 2 feet at this point

assayed: Gold, trace; silver, trace; tungsten, 4.05 per cent. It is evident from a small dump in a shed at the portal of the adit that the small amount of drifting yielded a very encouraging quantity of scheelite. The latter occurs in the form of graphite-coated nodular lumps, due to post-mineral movement, and lends itself readily to sorting by hand. Presumably at the time this mineral was struck the operators were interested only in gold-silver-lead possibilities and did not deem it worth further investigation. This showing appears to merit some further investigation which could be carried out at relatively low cost by hand-mining, because men and material can be transported by motor-boat from Hansard very readily and inexpensively. The advisability of continuing the drift started on the vein in both directions is indicated. A small amount of raising and sinking also seems advisable.

Silver.

This group consists of seven claims owned by Fred Peterson, of Prince George. The property is situated on and about 1 mile above the mouth of Averil creek, which flows into the Fraser river on the right bank of the latter about 1 mile east of the eastern boundary of Pre-emption Lot 9606. It is readily reached by motor-boat 24 miles from Hansard. The valley is somewhat deeply incised, affording numerous rock-exposures on the rims near the creek. A short distance from the creek, however, the ground is covered with a thick growth of timber and dense vegetation.

The formation, consisting of silicified quartz-sericite schist and quartz-biotite schist striking from north 77 degrees west to north 52 degrees west and dipping steeply south-west, contains several conforming quartz-filled shear-zones. Of these, only one of possible commercial significance reaches a maximum observed width of 10 1/2 feet and is exposed by surface and underground workings for a distance of 335 feet along its strike. It is filled with quartz-lenses and sheared rock and in the parting seams there is a heavy development of graphite. The quartz is sparingly mineralized chiefly with pyrite galena, and sphalerite, except in one place where heavy pyrite mineralization occurs. Scheelite was observed at one point in the outcrop, but this mineral has not at present been found in the underground workings.

The shear-zone is cut diagonally by Averil creek at two points, 135 feet apart, and the surface exposures occur at these points immediately above the creek, also

at a third point about 100 feet farther south-east on the line of strike. A 9-foot sample of quartz slightly mineralized with pyrite from the 10 1/2-foot shear-zone assayed: Gold, nil; silver, nil; tungsten, nil. Distant 135 feet on a bearing south 70 degrees east, the second outcrop occurs, on which the adit described below has been driven. The third outcrop is about 75 feet above the adit on the steep bank of the creek. While this outcrop is now rather obscured by sloughing, pieces of solid pyrite were observed at this point and also a little scheelite.

The adit, 203.5 feet long, is situated a few feet above creek-level, and for the first 126 feet follows a bearing south 77 degrees east, and for the remaining 77.5 feet a bearing south 72 degrees east. At the face on the north side a crosscut is driven a few feet towards the foot-wall.

The adit follows the hanging-wall of the shear-zone apparently throughout, the succession of mineralized quartz-lenses occurring on that side. These are to a great extent sparingly mineralized with pyrite and sphalerite. The first quartz-lens, 10 feet long, is 30 feet from the portal. Quartz appears at 65 feet from the portal and again at 120 feet, but is not continuous between these points, although it may exist in the foot-wall. The quartz-lens is continuous in the back of the adit between points 120 and 150 feet from the portal. At 160 feet another quartz-lens appears and continues for a length of 35 feet. The widest quartz-lens observed was 3 feet. The face exposes a width of 7 feet on the hanging-wall consisting of pyritized silicified quartz-sericite schist and brecciated material, in which are fragments of quartz mineralized with pyrite. The average dip of the hanging-wall in the adit is 76 degrees south-west. At the face the foot-wall of the shear-zone is not exposed.

Scheelite, so far as is known, has not been discovered in the adit, although it was observed in the outcrop. As mentioned, the latter is also heavily mineralized with pyrite at one point, but a sample of this assayed: Gold, trace; silver, 0.04 oz. per ton. A sample taken from a quartz-lens at 126 feet from the portal assayed: Gold, nil; silver, nil. The average amount of galena and sphalerite in the quartz-lenses is obviously low. A sample taken of selected mineral only assayed: Gold, trace; silver, 10 oz. per ton; lead, 11 per cent.

It is suggested that, inasmuch as the general character of this vein is very similar to that on the Ada claim described above, and as scheelite has been found at one point, some prospecting might be undertaken along the out-crop of the shear-zone at points farther southeast of the adit, in the hope that this mineral may be found."

THE CARIBOO AREA

The Cariboo is an active gold-mining area in Central British Columbia. That part with which this report is concerned centres about Wells and Barkerville, two towns, 4 miles apart. Wells, the larger of the two, is 278 miles in air-line northerly from Vancouver. It may be reached by road from Vancouver by following Highway routes 1 and 2 to Quesnel, 448 miles north of Vancouver, thence easterly along the Quesnel-Wells-Barkerville road for 58 miles to Wells. The nearest rail point is Quesnel, the northern terminus of the Pacific Great Eastern Railway. Quesnel is 347 miles by rail north of Squamish the southern terminus of the railway. Squamish is 50 miles by water from Vancouver and is served by a regular steamer service from that port.

Scheelite and its oxidation product, tungstite, are the only tungsten minerals known by the writer to occur in the Cariboo area. Scheelite occurs as the main constituent of quartz stringers and veinlets on the property of the Columbia Tungstens Co., Ltd., and as a minor constituent of the gold-bearing pyritic quartz veins of many of the gold mines. Tungstite occurs on the Taylor prospect.

The scheelite-bearing quartz veins of the Cariboo occur in slightly metamorphosed Precambrian quartzites, argillites and limestones, known as the Cariboo series. The series has been sub-divided into three formations: The Pleasant Valley, Barkerville and the lowest, Richfield. All the tungsten occurrences mentioned in this report are found in the Richfield formation, a formation that consists mainly of quartzite, but includes some limestone and black argillite.

Igneous rocks consist of a few dykes and sills of quartz-porphyry and other similar acidic rock-types, known as the Proserpine intrusives. They are considered to be pre-Mississippian and possibly Precambrian in age. Stock-like or larger masses of granitic rocks are absent. There are no large granitic intrusives anywhere in the region, and the nearest

small stock-like areas lie approximately 30 miles to the south-west of Barkerville. They consist of outcrops of granitic rocks on the Quesnel River (Lay, verbal communication), a large stock of alaskite on Spanish Mountain (Lay, VII, 1933, p. 135) and small areas of syenitic to monzonitic and pyroxenitic rocks in the Quesnel Forks area (Cockfield and Walker, VII, 1932, pp. 83 to 84).

The main structure in this belt of quartz-scheelite veins is a broad, north-westerly trending anticline, the medial part of which is exposed for a width of 15 miles and a length of more than 50 miles (Hanson, VII, 1935, pp. 1 to 2). With two exceptions, the scheelite occurrences mentioned in this report are on the north-easterly limb of this anticline. The two exceptions are the Taylor and Paxton prospects on the Snowshoe Plateau. These occur on the south-westerly limb at a place approximately three-quarters of a mile from the crest-line of the anticline.

In addition to being the main constituents in the veins of the Columbia Tungstens, Taylor and Paxton properties, scheelite is also occasionally found in minor amounts in many of the gold-bearing pyritic quartz veins of the gold properties in the Cariboo area. These properties include the Island Mountain, Cariboo Gold Quartz, Cariboo Thompson and Cariboo Hudson Mines. The veins in these mines are mineralized by gold, pyrite, arsenopyrite, galena, sphalerite, bismuth-lead sulphide, marcasite, telluride and scheelite in a gangue of quartz, ankerite and less sericite and calcite, (Hanson, VII, 1935, p. 12). In some veins pyrite comprises 50 per cent. of the vein by volume, but in most veins the quantity is much less; arsenopyrite is always a minor constituent.

In the gold properties, the scheelite occurs as scattered grains or more commonly as nodules, ranging from 1 inch to 6 inches in diameter, within the quartz and sulphides of many of the veins. The distribution of these nodules is very erratic. The chemical and physical factors controlling the localization of the scheelite are not evident, and it is impossible to predict its occurrence within a vein from any local geological or structural features of the vein. In the operating gold mines of the area, the distribution of the nodules is not sufficiently continuous within a vein to warrant the mining of even selected sections for scheelite alone. However, it is understood that in 1938, one gold property, the Cariboo Thompson, shipped 4 tons containing 500 lbs. of WO_3 from one short shoot of quartz-sulphide ore.

With the exception of the Cariboo Thompson, no attempt to date has been made by the Cariboo gold mines to save the scheelite. This mineral slimes very readily during grinding and although experimental work (II, Leaver and Royer VII, 1938) has been done on tailings elsewhere and scheelite concentrates obtained, very little has as yet been attempted on a commercial scale. However, it is understood that metallurgical experiments with a definite view of commercial production are being conducted on tailings from one of the larger Cariboo mills.

COLUMBIA TUNGSTENS COMPANY, LIMITED (HARDSCRABBLE)

The Columbia Tungstens Company, Limited, 19 Rector Street, New York City, owns several claims on Hardscrabble Creek; these claims, latitude north 53 degrees 8 minutes and longitude west 121 degrees 39 minutes, constitute the old "Hardscrabble scheelite deposit." They include two Crown-grants, the Mabel and Dawson, and the following nine mineral claims staked in 1936 and 1938, Mabel Extension, Dawson Extension, Dawson North-east, Dawson East, Dawson South-east Willow River No. 1, Willow River No. 2, South Mabel and South Dawson. The property extends up Hardscrabble Creek from its junction with Willow River. The main workings are on the Mabel and Dawson approximately half a mile above this junction.

The property is accessible by good motor-road from the town of Wells, 5 miles distant.

Scheelite appears to have been discovered on Hardscrabble Creek in 1904. Mr W. C. Fry found it in sluices while working his placer claim. The mineral was known locally as barite or heavy spar; however, it was correctly identified in the same year, 1904, by Mr. Austin J. R. Atkin, assayer and metallurgist and associate of Mr. C. J. Seymour Baker. The scheelite, as originally found, occurred only in gravel, but it was soon discovered in place and between 1904 and 1908 a shaft was sunk 30 feet in rock and a drift driven along the scheelite zone for approximately 60 ffet.

After 1908 very little work appears to have been done on the property until the summer of 1917 when the old workings were cleaned out and prepared for examination. At that time J. A. Macpherson of Stanley, B. C. was in control.

The workings as of 1918 have been described by Galloway (VII, 1918, p. 135) as follows:

"Entrance to the workings is by a shaft 60 feet deep, from which a drift extends northerly for 153 feet.

"At this point a winze has been sunk to a depth of 20 feet, and a drift run to the east for 49 feet. The main shaft is in gravel throughout, and the main drift north is in gravel for half its distance before breaking into solid rock.

"Thirty feet below these workings a drain-tunnel 1,900 feet in length was driven to draw the water from the gravel to facilitate the workings of the placer-gravel. South of the main shaft an opening downward connects with this drain-tunnel and the water is carried off. Above the main workings numerous gravel-drifts have been made in the course of mining out the auriferous gravel."

For some time after 1918 the workings seem to have been abandoned, for they are described in 1922 as being inaccessible. However, in 1927, the shaft was repaired and 400 lbs. of ore is reported to have been taken out by C. J. Seymour Baker, who held it under lease at the time from the Government. The property lay comparatively idle until 1935 when the present Columbia Tungstens Company Limited, began a small-scale development programme. Since that time, this company has carried on more or less continuous development. In 1937, a small pilot-mill was built and 100 tons of ore mined and milled, from which 1.5 tons of scheelite concentrates was obtained. In May 1938, the power-house and pilot-mill were completely destroyed by fire. However, by the summer of 1940 a new power-house and mill and several new camp-buildings, had been built. It is understood that the company is carrying on active development underground at the present time.

The workings are on a relatively flat part of a hillside that slopes gently southward down the course of Hardscrabble Creek toward Willow River. The area in the vicinity of the workings is densely wooded and covered with a considerable depth of overburden.

General Statement of local geology:

The rocks, as exposed in the underground workings are mainly grey, fissile quartzites and black to grey phyllites. They range in strike from north 65 degrees east to south 85 degrees east and in dip from 20 degrees to 47 degrees northward, nearly vertical dips were observed in only one place.

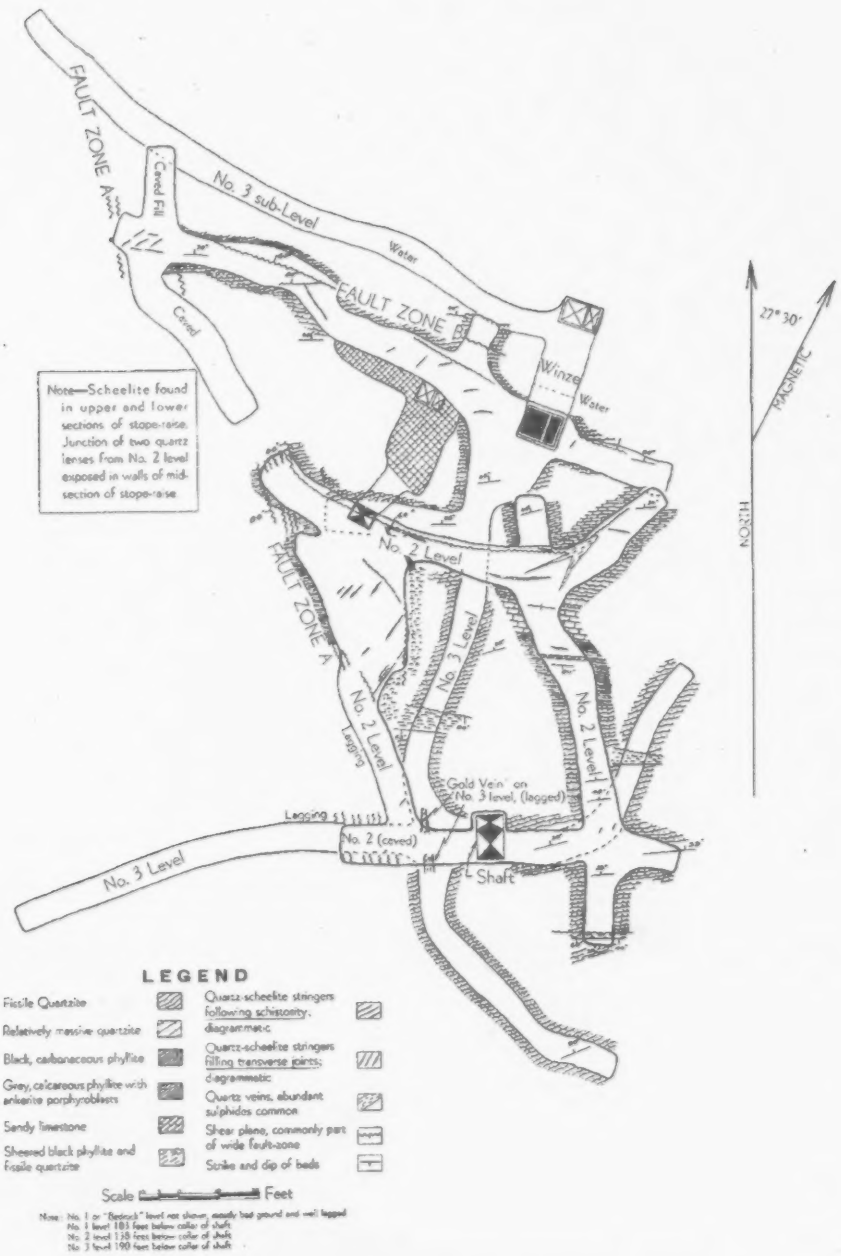
FAULT ZONE A
Caved Fill
No. 3 sub-Level
Water
FAULT ZONE
Caved
Winze
Water
27° 30'
MAGNETIC
NORTH
Note—Scheelite found in upper and lower sections of stope-raise. Junction of two quartz lenses from No. 2 level exposed in walls of mid-section of stope-raise
No. 2 Level
FAULT ZONE A
No. 3 Level
No. 2 Level
Logging
No. 2 Level
"Gold Vein" on No. 3 level, (logged)
Logging
No. 2 (caved)
No. 3 Level
L Shaft
LEGEND
Fissile Quartzite
Relatively massive quartzite
Black, carbonaceous phyllite
Grey, calcareous phyllite with anhedrite porphyroblasts
Sandy limestone
Sheared black phyllite and fissile quartzite
Quartz-scheelite stringers following schistosity, diagrammatic
Quartz-scheelite stringers filling transverse joints; diagrammatic
Quartz veins, abundant sulphides common
Shear plane, commonly part of wide fault-zone
Strike and dip of beds
Scale
Feet
Note: No. 1 or "Bedrock" level not shown, mostly bad ground and well logged
No. 1 level 181 feet below collar of shaft
No. 2 level 118 feet below collar of shaft
No. 3 level 190 feet below collar of shaft

Fig. 4. Columbia Tungstens Company, Limited (Hardscrabble). Plan of underground workings (after Company's plan) showing underground geology.

These rocks are cut by two fault-zones, the larger of which strikes north 20 degrees west and dips steeply south-westward, (Fault-zone A on Fig. 4), and the other strikes in general, north 70 degrees west and dips 60 degrees north-eastward (Fault-zone B on Fig. 4).

Mineralization has been varied, resulting in the formation of different types of quartz-sulphide and quartz-carbonate scheelite veins and veinlets which may occupy either faults or joints, or follow the schistosity of the enclosing rocks. The local structural control of the scheelite stringers at the Hardscrabble property, was not evident at the time of the writer's examination (June, 1940).

The property is in an area of rocks mapped as "Cariboo Series (undivided)" by Hanson (VII, 1938, Map 336-A) and no attempt at further subdivision of the rocks was made by him. The property lies athward the north-westerly projected position of the Barkerville Gold Belt. However, because of northeasterly-striking faults of unknown displacement that cut the rocks at points between this property and the gold properties in the Gold Belt, it is impossible to establish the stratigraphic position of the Hardscrabble rocks in relation to the rocks of the Gold Belt without further detailed areal mapping. One such fault has been mapped by Uglow (VII, 1926, Map accompanying Mem. 149), as being only about half a mile south-easterly from the property and as extending from Slough Creek north-westerly to the Willow River (idem.).

Igneous intrusives are lacking from the immediate vicinity of the deposit. The nearest are some pre-Carboniferous quartz-porphyry dykes and sills mapped on Shepherd Creek, approximately 4 1/2 miles easterly from the property. The nearest large area of intrusive rocks is on Mount Murray (Johnston and Uglow, VII, 1926, Map accompanying Mem. 149), approximately 7 miles easterly. Here Uglow maps an area 3 miles by 1 mile that consists predominantly of basic dykes and sills.

The rock-types on the property include fissile quartzite, relatively massive quartzite, calcareous phyllite, relatively pure phyllite and sandy limestone; the fissile quartzite is the most abundant rock-type. The distribution of these rock-types is shown in (Fig. 4). It is to be noted that these rock-types are somewhat gradational into each other, and that therefore the position of a plotted boundary between them is arbitrary.

The fissile quartzite is light grey in colour and vary-

ingly schistose in texture, the schistosity depending on the amount of micaceous material present. It characteristically consists of layers of relatively pure quartzite which range from 1/16-inch to 1 inch in thickness, separated by paper-thin layers of white mica or sericite. The individual beds of quartzite are frequently lenticular and gently plicated into shallow, open S-shaped folds. Under the microscope the rock is seen to consist of large grains of fractured, badly strained quartz set in an aggregate of finer grains of clear, unstrained quartz; sericite and occasional carbonate grains are also present. Grains of quartz that are both fractured and badly strained are prevalent in quartzite, that is neither in a fault zone nor immediately adjacent to it. This evidence of mechanical deformation in rocks neither in, nor adjacent to, zones of localized movement such as fault-zones, indicates that the quartzite in general has been subjected to widespread dynamic metamorphism.

Massive quartzite with beds up to 3 feet thick occurs at one place on Number 2 level (Fig. 4).

Phyllite, as applied by the present writer to the Hardscrabble rocks, is dark grey to black in colour and very thinly fissile in beds that are 1/16-inch or less in thickness. The beds consist of paper-thin to 1/16-inch layers of quartz grains, separated by films of micaceous material; a little chlorite is sometimes present.

A grey, calcareous phase of the ordinary phyllite occurs on Number 2 level (Fig. 4). This phase has a pseudo-porphyritic or porphyroblastic texture that results from the presence of well-shaped crystals of ankerite lying across the schistosity of the phyllite. The development of ankerite is probably due to recrystalization during metamorphism of calcareous matter originally present in the sediment.

A small amount of sandy limestone occurs on Number 2 level. This limestone is dark grey in colour and laminated in layers averaging 1 inch in thickness. In addition to abundant calcite, the limestone contains small amounts of quartz and sericite. The rock probably represents an impure, sandy, limy sediment.

The attitude of the rocks, as seen underground is fairly uniform. The strikes range from north 65 degrees east to south 85 degrees east and the dips from 25 degrees to 47 degrees northward. Departures from this range of strikes and dips are few; the most pronounced being in the east cross-

cut in Number 2 level where the fissile quartzite and adjacent sandy phyllite change from a dip of 25 degrees north-west to 80 degrees southeast.

Faulting of the rocks has been pronounced, but for the most part, it has been confined to two main fault-zones. The larger, marked (Fault-zone A on Fig. 4) strikes north 20 degrees west and the other marked (Fault-zone B on Fig. 4), strikes north 70 degrees west. Fault-zone A is reported to be as much as 40 feet wide, but owing to caved ground and lagging, only 20 feet of this width was seen by the writer. Where crushing and shearing have been most intense the material in the fault-zone consists of lustrous black, graphitic phyllite that is in part badly crushed and in part cut by numerous curved, slickensided shear-slips. In some places along fault-zone A, as in the vicinity of the ore occurrence on Number 2 level, the back of the workings consists of large areas of fissile quartzite and phyllite that are bounded by numerous slips and gouge seams. Many of these minor faults parallel the direction of the fault-zone and are undoubtedly genetically related to it.

Movement of ground within fault-zone A has been considerable, and the writer thinks that much of it is drag-ground. The two following features suggest this: (1) the occurrence of graphitic phyllite in a position that is athwart the strike of wall rock of a different rock type, namely fissile quartzite, and (2) the extreme friability of much of the quartz within the fault-zone. These two features are well shown in the vicinity of the scheelite-bearing ground in this zone on Number 2 level and in part on Number 3 level.

Insufficient data were available at the time of the writer's examination to establish the direction of movement along fault-zone A. However, the direction of bending of a quartz lens, where sliced by a shear-slip in the back of the west crosscut on Number 2 level, is such as to indicate that the east sides of slips have moved southward. Hanson (see marginal notes on Map 336-A, 1938, of the Geological Survey of Canada), notes that the movement along north-trending faults has been such that the east side of any one fault has been displaced southwards with respect to the west side. It has been impossible up to the present to determine the amount of displacement along the fault-zone.

Fault-zone B on (Fig. 4) is much narrower in width than fault-zone A. The surface of the main-slip in zone B curves slightly, but in its longest straight section it strikes north 70 degrees west and dips 60 degrees north-eastward. In gen-

eral, it is marked by a conspicuously slickensided hanging-wall and by 2 inches to 2 feet of crushed rock. A few minor slips branch at various angles from the main fault. A small amount of drag-quartz occurs in this fault on Number 3 level and some drag-scheelite on Number 2 level. The direction of movement along fault-zone B is only imperfectly known, and the amount of displacement not at all. If this fault is considered to be normal, the direction of fluting suggests that the north, or hangingwall-side, has moved down on a pitch-angle of 40 degrees in a direction north 45 degrees west.

Mineralization:

Mineralization has resulted in three kinds of veins (1) a gold-bearing lenticular quartz vein, (2) two apparently non-gold-bearing, quartz veins and (3) scheelite-bearing quartz veinlets or stringers.

On Number 3 level, at a point 10 feet west of the shaft, a quartz-sulphide lens that contains appreciable gold values has been cut; this has been referred to as the "Gold Vein" (Fig. 4). At the time of the writer's visit the lens had been tightly lagged because of bad ground, however, as seen between the lagging, the lens ranged in width from 6 inches to 2 feet. Two samples taken across 10-inch and 2-foot widths assayed: Gold, 0.26 ounces and Gold, 1.2 ounces per ton, respectively. Surface dump material, reported to be from this vein, was examined and several specimens were seen to contain free gold.

The two non-gold-bearing quartz-sulphide veins occur in Numbers 2 and 3 levels; a small one on Number 2 level, and a large one on Number 3 level at a point 20 feet northerly from the shaft (Fig. 4). The foot-wall of each vein is bounded by fault-gouge. The clean-cut nature of both walls and the fault-gouge on one wall of each vein suggests that these are quartz-villed fissure-veins. The vein-filling consists of quartz and the sulphides--pyrite, sphalerite and galena. Although sulphides are abundant, the amount of gold is negligible. A picked sample of vein-matter from the vein in Number 3 level assayed: Gold, nil; lead, 21-2 per cent.; zinc, 17.5 per cent.

The scheelite-bearing veinlets comprise two types, (1) filled "tension" joints that transect the bedding of the rocks, and (2) veins or stringers that follow the bedding and schistosity of the enclosing rocks.

The veinlets that occupy tension joints strike north 32 degrees east and dip steeply south-eastward; they definitely cut the bedding which, in the immediate vicinity of the joints strikes from north 65 degrees east to due east and dips 25 degrees north-westward. These veinlets range in length from a few inches to several feet, in width from 1/4-inch to 3 inches, and in spacing intervals from a few inches to several feet.

The bedding-plane veinlets and lenses tend to be more lenticular and discontinuous than those filling tension joints; a definitely lenticular cross-section is common. Although most of these follow the bedding, some of the lenses tend to cross it at small angles in the form of irregular veinlets. The lenticular veinlets range from 1 inch to several inches in width and from a few inches to approximately 1 foot in length.

The mineralogy of both types of veins is similar. The minerals, listed in order of abundance are: quartz, ankerite, calcite, scheelite and traces of sphalerite and galena. All of them are not always present in the same vein.

The amount and habit of scheelite is extremely variable, ranging from 100 per cent. in one kidney that measured 1/2-inch by 1 inch (Plate 1-B.) to a fraction of a per cent. in many veinlets. Within the quartz-ankerite veinlets the scheelite may occur as a middle layer of pure mineral, as disconnected patches or as thin irregular stringers more or less parallel to the wall of the veinlet. (Plate II-A) This varied habit is due to the different stages of replacement of the scheelite by ankerite and by a late generation of quartz. Slicing and crushing of scheelite and associated gangue minerals within veinlets that occur in the fault-zone on Number 2 level, indicates the pre-fault age of these veinlets.

Inasmuch as the veinlets are discontinuous and widely spaced, ordinary methods of channel-sampling are not satisfactory; the results of such sampling are only indicative of what the exposed rock surface contains. The only satisfactory type of sampling is obtained by running several tons of rock through a mill. This is the method, as of June, 1940, contemplated by the company.

The following samples, taken by the writer within fault-zone A where Number 3 level intersects it, are to be considered only indicative of the extent of mineralization as represented by number and size of scheelite veins:

Sample No.	Length Inches	Description	% - Assay WO_3
3390-B	24	Up south wall across crushed quartz-scheelite veinlets.	1.9
3391-B	46	Horizontally along south wall, no veinlets.	nil
3392-B	26	Diagonally across wall near back, across quartz-scheelite veinlets.	1.8
3393-B		Picked vein-matter from near face.	1.01

It is difficult to estimate tonnage of scheelite-bearing ground inasmuch as it is not defined by any vein-system or by any mineralized shear-zone. It is a matter of how close together the scheelite veinlets or lenses are and the amount of scheelite which these veinlets contain, that determines the extent to which ground may be considered potential.

Bearing in mind the statements in the preceding paragraph, the following sections may be considered as possible ore-bearing ground:

(1) Number 2 level, in west working that is partly stoped in vicinity of fault-zone A; this section measures approximately 30 feet by 12 feet wide, its vertical extent is unknown.

(2) Number 3 level, two sections in the west drift in vicinity of fault-zones A and B. One section in fault-zone A measures 10 feet long by 5 feet wide, the other section in the vicinity of the winze and close to fault-zone B extends east and west from the winze, and measures 50 feet long by 5 feet wide; the vertical extent of both sections is unknown.

All surface workings have either sloughed or been destroyed during mining operations. The underground workings consist of a vertical shaft 300 feet deep, from which three levels have been driven and a new one, Number 4, 111 feet below Number 3 level was started in June 1940. These levels

are numbered from the top down, namely Numbers 1 to 4 inclusive. All levels but Number 1 were examined by the writer. Number 1, also known as the "Bedrock" level, is in bad ground and so well lagged that a thorough examination was prevented. The plan of the Numbers 2 and 3 levels, with accompanying geology, is given in (Fig. 4).

The quality of the concentrates is high as is shown by the following analysis made in 1939 by the Department of Mines and Resources at Ottaw on 100 pounds of scheelite concentrates:

	Percentage
WO_3	78.51
CaO	18.97
P_2O_5	0.005
S	0.13
MnO	0.052
Fe_2O_3	0.73
Al_2O_3	0.60
MgO	0.051
SiO_2	0.17
Sb) As) Sn) Mo) Bi) Pb)	none detected
Ti	trace
Cu	0.002
Loss on ignition	0.30

This property was last examined by the writer in June, 1940.

TAYLOR PROSPECT

Scheelite has been recently discovered by Ed. Taylor, Wells P.O. on what Mr. Taylor referred to as the Gold Coin mineral claim, latitude north 52 degrees 52 minutes and longitude west 121 degrees 29 minutes, on the Snowshoe Plateau. The discovery was made at a point about 500 feet above the underground workings on the Hebson group, also owned by Mr. Taylor.

The property, at an elevation of 6,000 feet, is towards the south-westerly rim of the Snowshoe Plateau at the head of the west branch of Little Snowshoe Creek. The Snowshoe

Plateau, of an average elevation of 6,000 feet, lies between Barkerville and the settlement of Keithley Creek. The following streams rise in this Plateau: Keithley Creek, Swift River, Antler and Cunningham Creeks and the Swamp (Cariboo) River. Yanks Peak, at an elevation of 6,242 feet, is the highest mountain on the Plateau (see Cariboo Lake, sheet 94 A/14, National Topographic Series, Dept. of Mines, Ottawa).

The property may be reached either from Wells or Keithley Creek P.O.; the route from Wells is reported to be the better of the two, and was followed by the writer. From Wells the route is by a good motor-road fro approximately 23 miles to the Cariboo-Hudson, elevation approximately 5,500 feet, thence by a poor road for 1 1/2 miles and lastly by a good trail for 4 1/2 miles westerly to the workings.

The showings are in surface workings on the open, grassy top of the Plateau, at a point where the ground slopes gradually down over a distance of several hundred feet to the steeper slopes that form the south-westerly side of the Plateau. Rock outcrops are very scarce.

The tungsten occurs in a lenticular quartz-scheelite vein, strike north 60 degrees west and dip 75 degrees south-westward, that ranges in width from 1-inch to 4 inches and is exposed for approximately 18 feet before disappearing into sheared rock. The vein-shear cuts fissile quartzites and sericite schists that strike in general north 15 degrees west and dip 50 degrees south-westward; these rocks comprise part of the Richfield formation. In the vicinity of the vein-shear the rocks have been impregnated by small amounts of pyrite and galena.

Structurally the rocks in the vicinity of the Gold Coin form the south-west limb of a north-westerly striking anticlinal fold, the crest-line of which lies about three-quarters of a mile north-easterly from the property (Lang, Geol. Surv. Canada, 1938, p. 16, and Map 562-A).

The workings consist of two trenches and in one of them a shaft. Elsewhere two pits have been dug.

Number 1 trench extends north-westerly for 38 feet. It is 6 to 7 feet wide, 1 to 2 feet deep and towards the middle a shaft 6 feet in diameter and 6 feet deep is sunk.

Number 2 trench, in direction transverse to that of Number 1, lies north-westerly from it. The north-east end

of Number 2 trench, extending for 35 feet in a south-westerly direction, is 15 feet north from the north-west end of Number 1. It is 4 feet wide, 6 feet deep at its north-east end and 1 foot deep at its south-west end.

Scheelite was seen only in Number 1 trench.

The vein is a quartz-filled shear that cuts fissile quartzites and sericite schists. Its best exposure is in the north-west face of the shaft in Number 1 working, where the vein is slightly lenticular, ranging from 3 to 4 inches in width and is bordered by 1/8 inch of sheared rock. The vein-matter consists of large, poorly-defined crystals of quartz arranged perpendicularly to the walls of the vein and enclosing patches and crystals of scheelite. its oxidation product tungstite (Plate II-B) and stolzite. A small amount of galena occurs as widely-scattered grains in the adjacent sediments. The amount of scheelite is quite variable, ranging in places from a fraction of a per cent. to about 50 per cent. of the vein-matter. A representative 30-pound sample taken along the full 4-inch width of the vein and over a 4-foot length in the north-west face of the shaft assayed; Tungtic oxide (WO_3), 26.2 per cent.

The scheelite vein extends south-easterly for 18 feet from the north-west side of the shaft. The writer did not see any scheelite in the last 12 feet of the vein but it is reported to have been found when digging the trench. In a north-westerly direction the vein narrows to a barren shear within a few inches of the side of the shaft, and as such, disappears under the debris that covers the floor of the trench dug along the projected extension of the vein. No. 2 trench cuts across the projected strike of the vein at a point 30 feet north-westerly from the shaft but does not expose any vein-matter or well defined vein-shear.

The vein appears to cut three earlier bedded quartz veins, barren of scheelite. One of the bedded veins extends along a bedding plane in the sediments for a distance of 3 feet northerly from the scheelite vein. The other two bedded veins extend south-westerly from the scheelite vein for 1 foot along bedding planes of the sediments. These bedded veins appear to have been fed by the fissure now occupied by the scheelite vein. The formation of these bedded veins would therefore have antedated the deposition of the scheelite in the main vein.

A shallow pit has been dug in the banks of a small

southwesterly-flowing creek at a point approximately 570 feet north-westerly from Number 1 pit. This working exposes a small amount of galena which occurs as (1) grains in bedded quartz lenses 1-inch thick and 1 to 2 feet in length, and (2) as grains disseminated in fissile quartzite adjacent to the quartz lenses. A low percentage of pyrite and sphalerite is associated with the galena.

Fourteen feet upstream from the last pit, another working 6 feet in diameter and 5 feet deep, exposes a 2-foot length of a quartz lens 1 foot thick that contains pyrite, marcasite, galena and sphalerite.

The rocks in these two pits are nearly flat-lying, fissile quartzite that appears to strike in a general northwesterly direction and dip 10 degrees south-westward.

This property was examined by the writer in July, 1940.

PAXTON PROSPECT

Arthur Paxton and associates of Wells, B. C., own a group of mineral claims on the Snowshoe Plateau that comprises the Pacific Nos. 1 to 3 inclusive, and the Breakneck Nos. 1 to 3, inclusive; these were staked in 1937 and 1939.

The geographic position of the property is latitude north 51 degrees 52 minutes and longitude west 121 degrees 30 minutes. The showings at an elevation of 5,500 feet, are at the base of north-westerly facing bluffs that comprise Breakneck Ridge, a ridge on the west side of Aster Creek, a northerly-flowing tributary of the Swift River. (See Cariboo Lake, sheet 93 $\frac{A}{14}$, National Topographic Series, Dept. of Mines, Ottawa.)

Steep, rocky bluffs extend upwards from the showings for approximately 500 feet to the top of Breakneck Ridge. These bluffs appear to form the head of a small cirque, the floor of which slopes gently westerly from the workings downstream past the cabin.

The property may be reached from Wells by following a good motor-road for approximately 23 miles to the Cariboo-Hudson mine at an elevation of approximately 5,500 feet, thence westerly by poor road and trail over the Snowshoe Plateau, at elevations ranging from 5,500 to 6,000 feet for 7 miles to the showings.

The occurrence consists of scattered patches of schee-

lite in a quartz vein that ranges from 5 to 8 inches in width. In addition to the scheelite vein, three separate lenses of quartz, sparsely mineralized with sulphides, occur in the workings. They differ from the scheelite vein in being definitely lenticular and discontinuous within short distances.

The rocks comprise grey, fissile quartzite and a small amount of graphitic fissile argillite. They belong to slightly metamorphosed rocks of the Richfield formation as described by Lang (VII, 1938, pp 5 - 9). In the vicinity of the Paxton property, the rocks form the gently-dipping, south-west limb of a north-westerly striking anticline, the crest line of which lies approximately three-quarters of a mile north-easterly from the property. (Geol. Surv. Canada, Map 562 A). As far as the writer is aware, there are no granitic intrusions in the area.

The workings consist of one open-cut and one adit. Scheelite was seen only in the adit and in dump-material from the adit.

The open-cut has been driven south 50 degrees east for 27 feet to a 15-foot rock face. At a point approximately 10 feet from the mouth, this open-cut intersects a quartz lens 18 inches wide that strikes east and dips 70 degrees southward. The quartz contains a small amount of galena and pyrite. The south-west corner of the face exposes a larger lens that is approximately parallel to the first one and 10 feet distant southerly across the dip. The main part of the lens ranges from 18 inches to 2 feet in width, but in one 4-foot section it splits into three 6-inch veins that continue separately for a strike length of 4 feet and then coalesce again to form one vein or lens. The mineralization in this quartz lens consists of 6-inch clusters of sulphides, which contain abundant pyrrhotite, a little pyrite, sphalerite, chalcopyrite and galena. Neither of these lenses contain scheelite.

Beginning at a point 20 feet north-easterly from the mouth of the open-cut, a barren quartz lens outcrops for 25 feet in a north-easterly direction. The lens is 8 feet thick, strikes north-easterly and dips 50 degrees south-eastward.

From a point 15 feet below the open-cut and 25 feet in a direction south 70 degrees west from its mouth, an adit has been driven south 43 degrees east for 50 feet. Between points 25 feet and 40 feet, respectively, from the portal, the adit intersects the downward and south-westerly extension of the

large quartz lens that outcrops 20 feet north-easterly from the mouth of the open-cut. The two lenses that are exposed in the open-cut appear to be cut off in their downward continuation by a fault strike north 30 degrees east and dip 40 degrees south-eastward in the hanging-wall of the large lens, before they reach the level of the adit. The adit cuts the fault at a point 40 feet from the portal.

The adit intersects a scheelite-bearing quartz vein at a point 40 feet from the portal. This vein extends for a distance of 8 feet diagonally across the adit to the north-east corner of the face. The vein is 6 inches wide, strikes north 73 degrees west and dips 55 degrees south-westward. The vein-matter consists of abundant quartz, a little galena and pyrite and scattered clusters of scheelite. Only a little scheelite was seen in the adit but judging from an examination of material on the dump this mineral occurs in occasional patches from 1/2-inch to 2 inches in diameter within the quartz.

The same vein outcrops for a distance of approximately 6 feet at a point 25 feet above the adit but contained no visible scheelite.

The north-westerly extension of the scheelite vein is terminated by the fault at a point 8 feet north-west of the face in the hanging-wall of the large quartz lens; the south-easterly continuation on the surface is covered by drift, but the exposure in the adit, which is farther south-easterly along the strike, indicates that the vein continues in this direction.

This property was examined by the writer in July, 1940.

BRIDGE RIVER AREA

The Phillips' property on Tyaughton Creek is the only tungsten property in the Bridge River area. This is an active gold-mining section in the upper part of the Bridge River Valley, approximately 112 miles in an air-line northerly from Vancouver. Scheelite occurs in the quartz veins in several of the gold mines, but in such small amounts as to be of mineralogical interest only.

PHILLIPS' TUNGSTEN

Scheelite was discovered in the summer of 1939 in Tyaughton Creek Valley, in the Bridge River area, on ground

owned by Edwin Phillips of Minto City and staked originally for cinnabar. The property comprises the mineral claims Cinnabar Nos. 1 to 4, staked in July, 1938, Tyax Nos. 11 and 12, staked in October, 1936, and the Sandy Nos. 2 to 8 inclusive, variously staked September, 1936, August, 1937 and April 1938.

The property, at a latitude north 51 degrees 3 minutes and a longitude west 122 degrees 46 minutes, is on the east side of Tyaughton Creek at a point which is 2 miles by road northerly or up-stream from its confluence with Noaxe Creek, a westerly-flowing tributary of Tyaughton Creek (see Map 546A, Tyaughton Lake, Department of Mines and Resources, Ottawa, 1940). The exact position of the scheelite outcrop is described by referring its position to that of a cabin owned by Mr. Phillips. This cabin is on the east side of and adjacent to the road at a point which is 2.4 miles by road northerly up Tyaughton Creek from its junction with Noaxe Creek (see above Map 546 A). The scheelite occurs 65 feet above the road on the south side of a dry rock-gulch that crosses the road 1175 feet southerly from the cabin.

The scheelite showing is on an open hillside that slopes south-westerly with an approximate slope-angle of 30 degrees to the bottom of Tyaughton Creek. The ground is open, grassy, and in part, talus-covered and except for a few serpentine bluffs, is covered by an unknown depth of overburden.

The property may be reached conveniently by motor-road from Minto City by following the Tyaughton Lake road up the creek for approximately 14.3 miles from Minto City. Minto City is in the Bridge River Valley approximately 29 miles by good motor-road from Bridge River, a station on the Pacific Great Eastern Railway 105 miles north of Squamish. Squamish is the tidewater terminus of the railway approximately 50 miles up Howe Sound from Vancouver, and is served from Vancouver by regular boat service of the Union Steamship Company.

Geology. The distribution of rock types in the immediate vicinity is shown in (Fig. 5). In the following paragraphs the geology will be referred to the scheelite outcrop, as a reference point. A large irregular area of carbonatized serpentine, in which the scheelite veins occur, intrudes both ribbon chert and volcanics but is, in turn, intruded by many dykes and irregular masses of feldspar porphyry. The serpentine, forming the host-rock for the scheelite veins, extends as an irregular area for 200 feet north-westerly and south-easterly, 100 feet south-westerly, and 30 feet north-easterly from the scheelite outcrop. The serpentine has been extensively

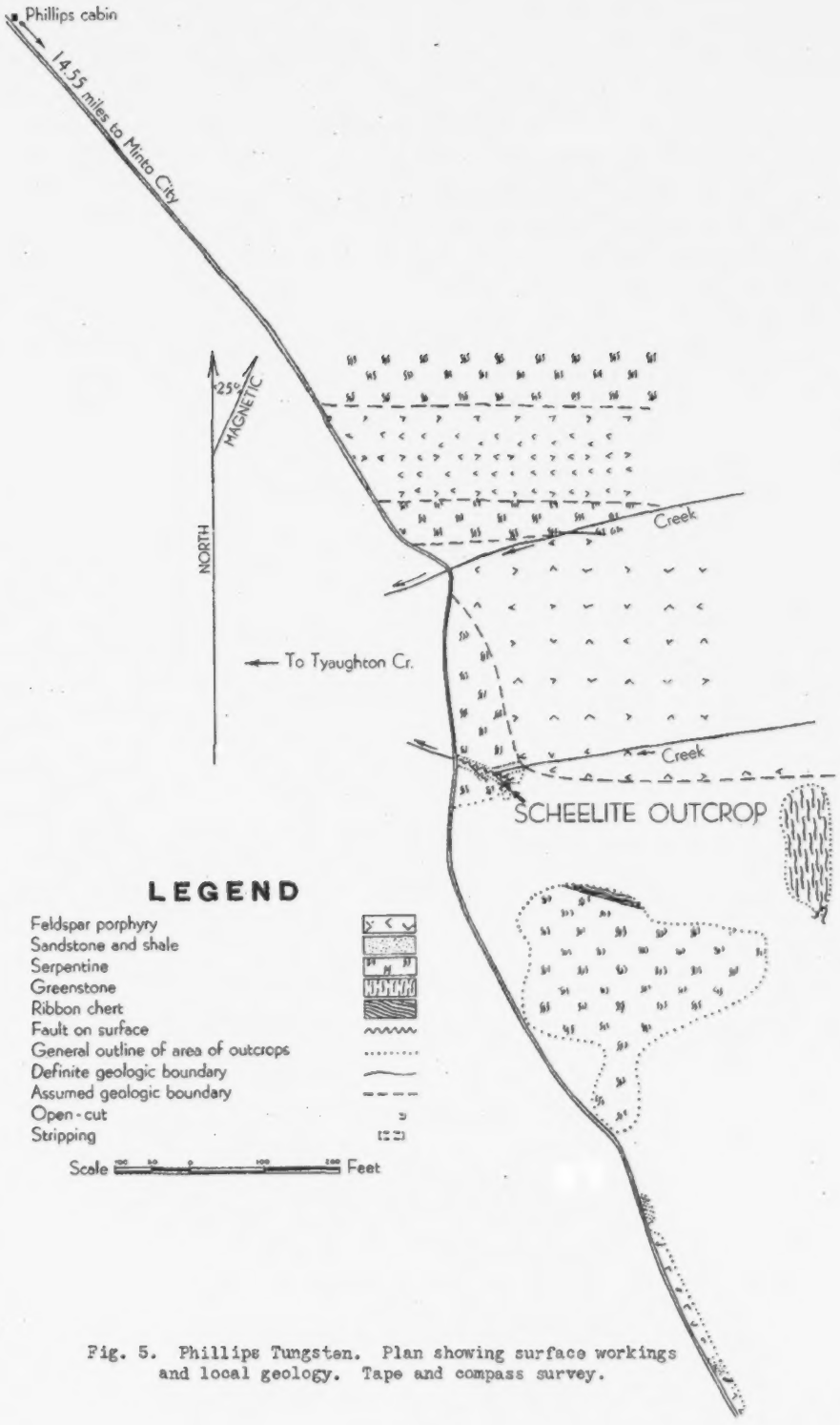

Fig. 5. Phillips Tungsten. Plan showing surface workings and local geology. Tape and compass survey.

carbonatized and consists almost exclusively of ankeritic carbonate with small amounts of mariposite, residual antigorite and chromite.

The ribbon chert, in contact with serpentine, outcrops approximately 200 feet south-easterly from the scheelite. The chert, strike easterly and dip vertical, consists of slightly crenulated ribbons of dark grey to black chert that range from 1 to 3 inches in width.

Volcanic rocks, or greenstone, consisting of flow rocks and volcanic breccia, begin to outcrop 400 feet easterly from the scheelite and extend for an unknown distance eastward. The flow-rocks consist of massive, fine-grained andesitic lava with an amygdaloidal phase. The volcanic breccia consists of poorly defined angular fragments of andesitic material similar to that of the flow rocks, and set in an altered groundmass of the same material.

Feldspar porphyry, the youngest rock on the property, occurs as dykes that range from 500 to 100 feet in width, and as an irregular stock-like area with an exposed diameter of 300 feet. It is a medium-grained, porphyritic rock that contains closely-packed feldspar phenocrysts, averaging 1/8-inch in maximum dimension, set in a brown weathering, altered matrix consisting mostly of carbonate. No quartz was seen in any of the specimens examined.

Veins.

The scheelite outcrop consists of two small parallel veins, one of which is predominantly stibnite and the other predominantly scheelite. These veins are 2 feet apart and range from 1 inch to 3 inches in width. They strike north-westerly in conformity with the contact between the serpentine and feldspar porphyry but lie 30 feet south-westerly from the contact.

Over the short distance exposed, the veins maintain a uniform strike and dip, and a fairly uniform width. They frequently split and smaller veins branch sharply from the main vein, and extend for 2 or 3 feet into the wall-rock and die out or may turn, following other branch-fractures that lead back into the main vein. Shearing along the vein walls and branch-fractures appears to have been absent for there are no slickensides and the veins are frozen to the wall-rock. This branching type of fracture is suggestive of fracturing under a light load, presumably near the surface.

The veins show marked crustification or banding by deposition. Crustification is particularly well shown in the stibnite-scheelite vein where scheelite is followed inwards from both walls of the vein by finely crystalline chalcedonic quartz, then by coarsely crystalline comb-quartz, and finally by a central band of stibnite.

A definite comb-structure is shown both by the coarsely crystalline quartz and by the scheelite. This structure is expressed in the development of pyramidal crystals that have grown normal to the walls of temporary openings within the vein.

Mineralogy. The vein-minerals include, listed in order of abundance: scheelite, stibnite, quartz and carbonate. These minerals are distributed between the scheelite vein and the stibnite-scheelite vein. The scheelite vein (Plate III-A) ranging from 1 to 3 inches wide, consists predominantly of scheelite and carbonate with some quartz and isolated crystals of stibnite. In sections of the vein, sometimes as much as 3 feet in length, scheelite amounts to 75 per cent. of the vein-matter (equivalent to assays of 60.7 per cent. WO_3). In other sections there is less scheelite and in places it is completely replaced by carbonate. The stibnite-scheelite vein, ranging from 1 inch to 3 inches wide, consists predominantly of stibnite with varying amounts of scheelite, carbonate and quartz. Scheelite is more abundant in the stibnite vein than stibnite in the scheelite vein; in one place the scheelite amounts to 38.5 per cent. (equivalent to 31.1 per cent. WO_3) of the vein-matter.

A partial analysis of as pure a sample of scheelite as could be obtained by panning and by separation with methylene iodide, gave the following results:

WO_3	79.7 per cent.
CaO	19.3 per cent.
MoO_3	trace

At the time of the writer's examination, the only development work on the scheelite veins consisted of a stripping measuring 4 feet wide by 14 feet along the strike. At a point 450 feet in a direction south 65 degrees east from the scheelite stripping, a small open-cut has been driven northerly for 20 feet on an outcrop of greenstone containing very sparsely disseminated grains of cinnabar.

A small production of hand-mined and cobbed high-grade

vein-matter has been made by Phillips and associates.

This property was examined by the writer in September, 1939.

SKAGIT RIVER AREA

Scheelite has been reported from the Skagit River area by Cairnes (VII, 1920, p. F-9). It occurs on the Mammoth group approximately latitude north 48 degrees, 12 minutes, longitude west 125 degrees 4 minutes, in the old Twenty-three mile camp, at the junction of the Skagit and Sumallo Rivers, a point approximately 23 miles by an old road that extends south-easterly from the village of Hope.

The scheelite occurs in a vein about 3 feet wide that follows the west-wall of a calcic-silicate zone about 50 feet wide. It is associated with various calcic-silicates which include abundant anorthite, feldspar and actinolite and with the sulphides, nickeliferous pyrrhotite and sphalerite. Very little work appears to have been done on this property.

NICOLA AREA

In the Nicola area the only scheelite reported came from the Joshua vein on the property, latitude north 50 degrees 21 minutes, longitude west 120 degrees 24 minutes, of the Nicola Mines and Metals, Limited near Stump Lake. The scheelite, mostly orange-coloured (P. B. Freeland, personal communication), has been reported by Hedley (1936, VII, p. D-15) as being of rare occurrence and the amount is apparently negligible.

NORTHERN OKANAGAN AREA

Tungsten reported from this area is from the White Elephant group, (Precambrian Gold Mines, Ltd.) latitude north 50 degrees, 9 minutes, longitude west 119 degrees 32 minutes, a gold property, 2 miles west of Okanagan Lake and about 36 miles south-westerly from Vernon. Concerning this reported occurrence, Cairnes says (VII, 1931, p. 87-A, footnote): "The writer was informed that some scheelite had been associated with the quartz in the outcrop." The shearing on the White Elephant group consists of a large quartz lens 60

feet long by 50 feet wide at the surface, but longer underground, that has been mineralized by small amounts of pyrrhotite, pyrite, chalcopyrite and locally, a moderate amount of the gold-bearing bismuth telluride, tetradymite. Cairnes does not mention scheelite underground. The country rock is granite.

BEAVERDELL AREA

The Beaverdell area is in south central British Columbia and centres around Beaverdell, a village on the Kettle Valley branch of the Canadian Pacific Railway, 261 miles east of Vancouver, or 93 miles east of the town of Penticton. It may be reached by motor-road easterly from the town of Kelowna, 46 miles distant. Kelowna is on the Okanagan Highway route No. 5, 328 miles easterly from Vancouver.

Scheelite in small quantities occurs in several of the calcic-silicate zones in the Beaverdell area, but development to date, August, 1940, has not exposed economical amounts.

ELITE

This prospect consists of the Elite mineral claim staked in July, 1940, and owned by Victor F. Locke of Kelowna. B. C.

The claim, latitude north 49 degrees 34 minutes, longitude west 119 degrees 6 minutes, is on the west side of Arlington Mountain, approximately 5 miles north of Carmi. Carmi is on the Beaverdell-Kelowna road at a point 5 miles north of Beaverdell. The workings are 1 1/2 miles west of the highway.

The workings, at an elevation of 3,500 feet, may be reached by following a compass-line on a bearing (astronomic) of north 30 degrees west for 1 1/2 miles from a point, elevation 2,900 feet, on the Carmi-Kelowna road that is 5 miles north of Carmi.

The hillside in the vicinity of the showings is the gentle westerly slope of Arlington Mountain. It is densely wooded and although covered by only a foot or two of overburden in many places, outcrops in the vicinity of the workings are scarce.

The scheelite showing consists of an area approximately 15 feet in diameter of calcic-silicate rock that contains scattered grains of scheelite. Quartz-diorite occurs 50 feet northerly from the workings.

The calcic-silicate rock consists of light green, dense diopside, granular, brown garnet and some granular calcite and epidote and quartz.

The scheelite occurs as grains disseminated throughout the rock, showing a preference for areas of quartz and, occasionally, as short-hair-like veinlets in quartz. The amount of scheelite is so small that samples of selected specimens in excess of 5 pounds are usually too low in scheelite to give a recordable assay in tungstic oxide, WO_3.

All the workings are old, apparently antedating the year 1915, the date of publication of a report by Reinecke (VII, 1915, pp. 142-143) in which he mentions the scheelite occurrence. No recent work other than sampling of the small dumps has been done on the showings.

The workings consist of three pits. An upper one 6 feet in diameter by 6 feet deep; a second one 5 feet lower and 15 feet westerly from the first and 5 feet in diameter by 4 feet deep, and a third one, 10 feet below the second and 40 feet in a direction south 20 degrees west from it. All these pits show small amounts of scheelite.

OTHER OCCURRENCES IN THE BEAVERDELL AREA

Mr. Victor Locke, owner of the Elite mineral claims, showed the writer two other occurrences of scheelite. One, at latitude north 49 degrees 34 minutes and longitude west 119 degrees 4 minutes, was on the east bank of the West Fork of the Kettle River opposite a point on the Beaverdell-Kelowna road, 5 miles north of Carmi. The other showing was on Knob Hill, latitude north 49 degrees 30 minutes and longitude west 119 degrees 2 minutes and approximately 7 miles north-east from Beaverdell up Beaverdell Creek.

Kettle River. The Kettle River occurrence is in a band of garnetiferous limestone that extends south-easterly from the east bank of the river for 500 feet over an outcrop width of approximately 100 feet.

The outcrops are in an area that consists of low knolls, 20 to 40 feet high, in a badly burnt-over area.

The mineralization, as seen in the outcrops and surface pits, consists of a few grains of scheelite scattered indiscriminately through garnetiferous limestone. Garnet, the brown andradite variety, occurs in small irregular patches

throughout white, crystalline limestone; the scheelite present favours the garnet areas. The amount of scheelite in these showings is negligible.

The only working on these outcrops consists of one open-cut 3 feet deep on the west slope of a knoll 40 feet high and 120 feet from the river-bank.

Knob Hill. The Knob Hill showings may be reached from Beaverdell by following the road north-easterly up Beaverdell Creek for a distance of 7 miles, then by a westerly route through open pine-woods of the hillside to an elevation of 4,300 feet. The hillside in the vicinity of the workings is relatively open, covered with range-grass and pine trees and slopes gently north-westerly.

The occurrence consists of minute grains of scheelite sparsely disseminated through calcic-silicate rock that is composed of diopside, brown garnet, calcite and quartz. A 4-foot granite dyke cuts the calcic-silicate rock.

No structural control of the scheelite mineralization by faults or favourable zones is apparent.

The workings consist of an old vertical shaft, 25 feet deep, a pit 8 feet in diameter by 4 feet at a point 5 feet north-easterly, from the shaft and a trench 3 feet wide that extends for 40 feet in a north-westerly direction from the pit. From a point 20 feet south-easterly from the end of the trench a branch-trench extends south-easterly for 15 feet towards the shaft.

Calcic-silicate rocks sparsely mineralized with scheelite occur in all the workings. Much of the mineralized rock was examined in ultra-violet light and that showing the best scheelite was assayed for tungstic oxide, WO_3. However, the amount of scheelite even in the best specimens was too small to give a recordable assay in tungstic oxide. The showings, as they existed when examined by the writer, do not expose any mineable ore.

The Beaverdell scheelite showings were examined by the writer in August, 1940.

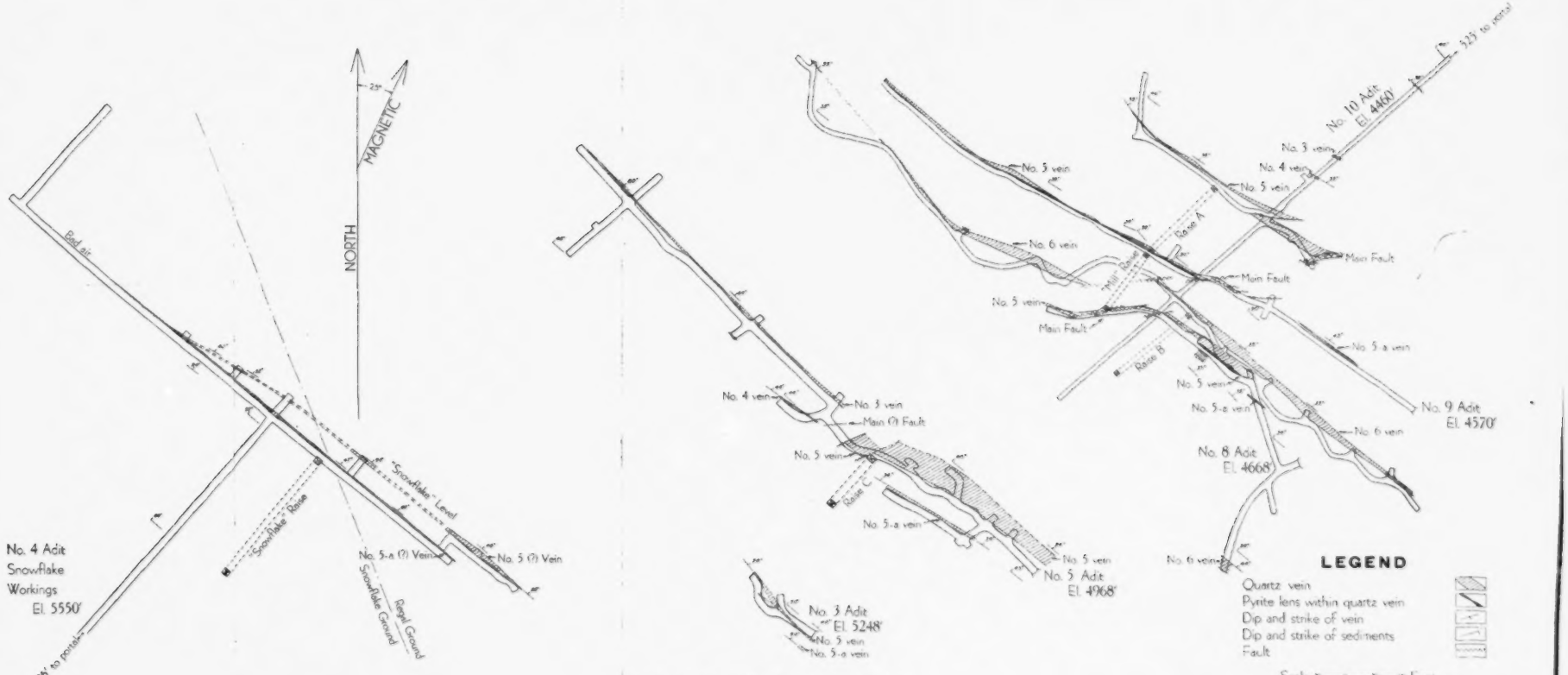

Fig. 6. Regal Silver. Plan of underground workings (after Company's plan) showing distribution of veins and faults.

REVELSTOKE AREA

The Regal Silver, near Albert Canyon, is the only property known to contain scheelite in the Revelstoke area. The general geology of this section is given in the following report.

REGAL SILVER

The Regal Silver property, comprising the Crown-granted mineral claims Joy, Alice, Helena, Bee, May, Cora, Emily, Annie, Nestoria, Francis, Hilda and Big Ledge No. 2, owned by Mrs. Emily Woolsey, is under option to W. S. Campbell and associates of Edmonton, Alberta, as of October, 1940.

The property is on the west side of Clabon Creek, a southerly-flowing tributary to Woolsey (Silver) Creek. Woolsey Creek flows south-easterly into Illecillewaet River at a point approximately 1 1/2 miles down-stream from Albert Canyon, a flag-stop on the Canadian Pacific Railway 20.9 miles east of Revelstoke. The camp is at an elevation of 4,455 feet, and the workings (Fig. 6), all underground, are between elevations of 4,455 and 5,550 feet. The Snowflake property adjoins the Regal Silver on the west.

History.

This property in 1918 consisted of seven claims. The original group of four claims, staked by C. E. Kennedy in 1918, was acquired by David Woolsey, who added these claims to the group during that year when the property became known as the Woolsey group. It is believed that Woolsey did the first surface and underground work, presumably in No. 3 adit, in 1918. The following year the property was bonded to a company represented by C. V. Brennan and the present No. 5 adit was commenced and drive 120 feet. In 1920 development work is reported to have been done by David Woolsey and his two sons.

In 1925 the property was acquired by the Bernier Metals Corporation of Vancouver, who made considerable surface improvements and started the present No. 10 adit. In 1926 further surface work was done and the No. 10 adit driven for approximately 200 feet. This work, including additional development in No. 5 adit, was continued by the company until 1927.

In December, 1927, the Bernier Metals Corporation ceased to function and was succeeded by the Morton-Woolsey

Mines, Limited[1], which in turn gave an option to the Buck and MacCulloch Syndicate in March, 1928; this syndicate incorporated the Regal Silver Mines, Limited[2]. During 1928, No. 10 adit was extended to cross-cut the Nos. 5 and 6 veins along which drifting was done. In 1929, No. 10 adit was extended and an intermediate level, now No. 9 adit, was started. In 1930, considerable underground work was done consisting of exploration on Nos. 9 and 10 adits, the starting of No. 8 adit and the extension of the No. 4 adit of the Snowflake workings from Snowflake ground into the adjacent Regal ground.

In 1939 the property was operated by A.S. MacCulloch and associates. Ore tests were made with the object of producing a scheelite concentrate suitable for marketing. A small underground mill of approximately 25 tons rated capacity was installed. It is reported that this mill only ran two weeks and that no concentrates were shipped.

In August, 1940, Edmonton and Vancouver interests, headed by W. S. Campbell of Edmonton, re-opened the property, tore out most of the machinery composing the 1939 underground mill and commenced the installation of equipment for a small pilot mill. This work was being done at the time of the writer's examination in October.

Access and Topography.

The property is reached by caterpillar road from Silver Creek siding on the Canadian Pacific Railway, approximately 1 3/4 miles west of Albert Canyon. The caterpillar road climbs approximately 2,300 feet in a distance of 7 miles from the siding to the mine-camp.

The workings, all underground, are on a steep hillside that slopes with an average angle of 26 degrees into the bed of Clabon Creek. Slide rock and low bush characterise the adjacent hillside. Rock bluffs, though not present in the vicinity of the workings, are numerous and extensive a few hundred feet above. The bluffs are the starting points for many snow slides during the winter season. As a result, care must be observed in the choice of building sites in order that places free from snow slides may be chosen. This is not easy.

Geology.

The deposit consists of scheelite in bedded quartz-sulphide veins which lie within black to grey slates. No

1. Company dissolved February, 1941.
2. Company struck off August, 1940.

igneous rocks were noted on the property.

The slates are part of a belt of slightly metamorphosed Precambrian sediments which strike north-westerly and dip eastward. This belt is approximately 14 miles wide and extends for several miles north-westerly and south-easterly. The Regal-Silver lies approximately 3 miles within the south-westerly boundary of the belt.

To the south-west, across the strike, this belt of slightly metamorphosed sediments is succeeded by a short discontinuous belt, approximately 2 miles wide, of more highly metamorphosed sediments consisting chiefly of quartzites and schists. These rocks are in contact to the south-west with a large area of schists, gneisses, gneissic granites and pegmatites (VII, Gunning, 1928, p. 149), a lithological group of rocks to which Daly (VII, 1913, p. 35) gave the name "sill-sediment complex."

Granitic rocks do not occur on the property. The nearest areas of granite are two stocks, one of which outcrops 7 miles north-east of the workings in the vicinity of Fang Rock (see map No. 237A in report by Gunning, 1928) and the other outcrops 8 miles to the south-east on Albert Creek south of the Illecillewaet River. (idem. 1928, pp. 144-148).

The granitic tongues in the complex immediately to the south-west indicate the presence of an underlying mass of granite. This inferred mass of granite, extending north-westerly, would underlie the Regal scheelite occurrence and serve as a source for the mineralizing solutions responsible for the veins on the property.

The rocks on the property are black to grey, graphitic slates or slaty argillites, some of which are slightly limy. They are fairly uniform in attitude, varying in strike from north 40 degrees to 60 degrees west and in dip from 30 degrees to 60 degrees north-eastward. Other sedimentary types and igneous rocks are absent from the vicinity of the workings.

Folds.

Folding on a small scale has not occurred within the limits of the underground workings; the rocks strike north-westerly and dip south-eastward with no reversals of dip. This corresponds to the regional structure of the area which has been described by Gunning (VII, 1928, p. 151), as follows:

"The major geologic structure is a broad synclinal trough whose axis trends north-west-southeast through the centre of the mapped area. Within this major syncline the rocks are complexly folded into a series of synclines and anticlines whose axes, on the whole, parallel the regional strike of the sedimentary formations and plunge towards the south-east."

Although the strike of the rocks in the workings is fairly constant, the dips show a progressive and general flattening as from the uppermost to the lowermost levels. In general, the dips in the uppermost or Snowflake level are between 60 and 55 degrees, this figure changes through 50 and 45 degrees in No. 5 adit to 40 and 35 degrees in Nos. 9 and 10 adits. This tendency for the rocks to flatten in a north-easterly direction suggests the presence of a synclinal trough in that direction. Without more field data it is impossible to predict how far north-east the axis of this fold would lie.

Faults.

Post-vein faults are widespread. The faults are of two main types: (1) transverse, inter-vein faults that cross-cut the veins and offset them across their strike, and (2) Parallel, intra-vein faults that parallel the veins, lie within them and displace the walls of the vein by unmeasurable amounts. The inter-vein faults can be seen in (Fig. 6), but because of difficulty in clear representation the intra-vein faults have only been occasionally shown.

The main transverse inter-vein fault is one that strikes east and dips steeply northward. It has been cut on all levels but No. 3 and the Snowflake level. The fault-zone consists of abundant crushed graphitic slate (Plate IV-A). Numerous curved slips follow the crushed slate in some branch into the wall rock. Depending on the abundance and compactness of these slips, the main crush-zone ranges from 1 foot to 10 feet in width. Crushing within the zone appears to have been intermittent and interrupted by one main period of quartz mineralization. In many places the zone contains slightly deformed stringers and small lenticular bodies of quartz (Plate IV-A) lying within the sheared graphitic slate and roughly parallel the main direction of the fault-zone; no minerals other than quartz appear to have been formed at this time. Because of the deformation and fracturing of these quartz veins and stringers, faulting within the zone

was apparently continued after the deposition of the quartz. The formation of quartz in the fault-zone no doubt completely post-dates that of the main quartz-sulphide veins.

Displacements within the plane of the main fault, as measured in the drifts and as calculated from vein offsets, are as follows: dip-slip, 55 feet; strike-slip, 100 feet; net slip 115 in a direction inclined at 30 degrees below the horizontal in a north-easterly direction. Because of variations in the dip of the fault, the figures for heave and throw of the faulted vein vary slightly from place to place; however, the figures are close to those pertaining to the displacement on No. 8 level, namely, a heave of 20 feet and a throw of 50 feet. Other faults of much smaller size occur at other places underground, (Fig. 6). Displacement along these has amounted to only a few feet and has not caused any trouble in locating the faulted segments of the vein.

Veins.

At least five separate quartz-sulphide veins have been cut in the underground workings. These veins are all more or less parallel to one another and to the enclosing slates, although occasionally cutting the slates at small angles, and may be classed as bedded veins. They range in strike from north 45 to north 65 degrees west, in dip from 34 degrees to 60 degrees north-eastward and range in width from a few inches in places where the vein-matter disappears along a fault to as much as 30 feet; however, widths between 2 and 8 feet are more common. The maximum length of any one vein is not known, but 1,000 feet of vein-matter is exposed in No. 6 vein on No. 10 level (see Fig. 6).

A distinct ribbon-texture (Plate IV-B) is characteristic of much of the vein-matter. This texture is manifested by bands and ribbons of either unreplaced slate or of pyrite which has favoured deposition along these ribbons. Even where sulphides are abundant the vein is definitely banded. This banding is disconnected and irregular and is therefore considered to be inherited from an earlier ribbon-texture rather than caused by repeated re-openings by fissuring within the vein. In extreme cases slate forms the bulk of the vein-matter, and vein-quartz tends to form stringers along the slate, finally ending as a few veinlets of quartz.

The intra-vein faults are not so conspicuous as the transverse, inter-vein faults, inasmuch as they follow the vein and are usually plainly evident only where they follow

pyrite lenses or leave the veins along their strike. These faults are commonly marked only by thin clay slips in either the hanging- or foot-wall of the vein. Where they follow pyrite lenses the slips widen to crush-zones up to 1 foot in thickness; usually, however, they are marked by 1/2-inch to 6 inches of crushed pyrite. Abundant slickensiding, expressed by mirror-like surfaces on the pyrite along slip-walls and occasional superposition of the vein, indicate that considerable movement has occurred along these intra-vein faults. However, there are no markers either within the vein or in the vein-walls to determine relative movements within the plane of the fault.

Determinations of relative movement along the faults and the direction of movement are of importance in, (1) attempting to correlate the various scheelite-bearing pyrite lenses cut in the drifts and (2) in trying to determine the extent of any lens up and down the dip of the vein. With such extensive intra-vein faulting present and no information concerning the displacement along these faults, prospecting for the extension of these pyrite lenses beyond their apparent termination, is difficult without definite working clues.

Mineralogy.

The mineralogy of the veins consists of scheelite and pyrite, sphalerite, galena and small amounts of stannite, all in a quartz gangue. In addition to these, Gunning (VII, 1931, p. 217) mentions microscopic amounts of tetrahedrite, ruby silver, native silver and chalcopyrite from the Snowflake ores. The writer has not studied the Regal ores under the microscope, but considers it probable that these minerals are present in similar amounts. In most places quartz is the more abundant constituent, the combined sulphides and scheelite generally amounting to less than 1 per cent. of the vein-matter.

The scheelite occurs (1) in small amounts indiscriminately scattered at wide intervals throughout the quartz veins, and (2) in relatively larger amounts confined to four thin pyrite lenses or ribbons which lie within Nos. 5 and 5A veins. In the first mode of occurrence, scheelite is found either as thin, microscopic films that usually parallel the ribbon-structure of the veins, or as occasional grains which range from microscopic size to 1/4-inch in diameter and are usually associated with small pyrite clusters. The scheelite is at first only recognisable by its fluorescence in ultra-violet light. In the second mode of occurrence schee-

lite is within pyrite lenses. These lenses range in length from a few feet to 250 feet, and in thickness from 1 inch to 18 inches, although 6 inches is a more common width. The amount of scheelite in these lenses is very variable, ranging from a few microscopic specks to one kidney of relatively pure scheelite measuring 2 feet long by 4 inches wide (Plate III-B). In general, the scheelite occurs either as short thin kidneys (Plate V-A) or as ribbons that parallel the walls of the pyrite lenses. The ribbons range from 1/32 to 3/4 of an inch in thickness and from 1 inch to several feet in length. They commonly consist of disconnected grains and small patches of scheelite (Plate V/B) and less rarely of a solid band of the mineral. To a large extent, pyrite and quartz replace the scheelite in the ribbons and accounts for much of its discontinuity along the strike.

Pyrite is the most common sulphide in the quartz veins and is abundant at many places in the slate wall-rock. Like the scheelite, pyrite occurs either scattered in small amounts throughout the quartz veins, or concentrated into scheelite-pyrite lenses described above. The pyrite lenses are commonly the locus of extensive intra-vein faulting. As a result, pyrite grains are commonly broken and in the faults the grains are crushed to material of gouge-like consistency. Many of the pyrite grains in the vicinity of the faults are coated by films of graphite. This graphite has probably resulted from the extreme crushing of pyrite-bearing, graphitic slate adjacent to the veins.

Galena and sphalerite, found together in widely scattered areas throughout the quartz veins, usually occur as small walnut-sized patches within the quartz. In a few places a few hundred pounds have been mined from rich pockets. The galena is the usual steel grey, cubic-cleaved variety. The sphalerite is noticeably light brown in colour and is almost a resin-jack.

Stannite occurs in small quantities associated with the pyrite. Excepting in No. 5A vein in the Snowflake adit, it is seldom recognisable in a hand specimen. In this vein stannite is found in the drift in the vicinity of the raise and in the lower 50 feet of the raise in patches up to 2 feet in diameter, that consist roughly of one-third stannite, one-third pyrite and one-third quartz gangue. Small segregations of scheelite were seen associated with the stannite.

Excepting for slate partings, gangue in all the veins

is entirely milky quartz. The only carbonate seen was a 2-foot pocket of calcite lying within the main fault-zone on No. 10 level. Inasmuch as the fault post-dates the quartz veins, the formation of this calcite must also post-date them.

Individual Description of the Veins.

For purposes of description, these veins have been numbered as from the hangingwall-side to the footwall-side; numbered thus they are Nos. 3, 4, 5, 5A and 6 (Fig. 6). Of these, No. 5 is the most important as far as scheelite-bearing vein-matter is concerned.

No. 3 vein has been found on level Nos. 5 and 10, (Fig. 6). Its usual width is approximately 2 feet, but it widens to a maximum of 5 feet in No. 5 adit, then narrows towards the north-west end of the same adit to a 5-inch ribbon of crushed material in an intra-vein fault.

No. 4 vein has been found on adits Nos. 5 and 10. Measured across the dip it is 25 feet below No. 3 vein. It is similar in range of widths to No. 3 vein.

No. 5 vein, the only one in which scheelite occurs in appreciable amounts, has been found in the following adits: Snowflake level and Nos. 3, 5, 8, 9 and 10, (Fig. 6). Measured across the dip it is 50 feet below No. 4 vein. Seen in short sections the vein appears to be tabular and of a uniform width. However, because of discontinuous ribboning that is manifested by dying out and coming in of quartz bands within the general boundaries of the veins, the actual width of vein-matter is variable along drift-sections. This variation in width is noticeable on all levels, but particularly so on No. 9. On the Snowflake level, No. 5 vein ranges from 2 to 11 feet wide, but towards the north-west end of the drift it diappears in sheared rock and crushed vein-quartz along an intra-vein fault (Fig. 6). On No. 3 level it ranges from 6 inches to 4 feet. This vein reaches its maximum width of 30 feet in the side drift on No. 5 level, but decreases to 11 feet on its strike north-west towards the main fault. In general, however, the widths are much less and within the wider sections of the veins, bands of slate are common. On No. 8 level the range in width is from 3 to 11 feet, on No.9 from 1 to 6 feet and on No. 10 from 1 1/2 to 12 feet of quartz and towards the extreme north-west end of the drift on this level the vein narrows to 3 inches of pyrite. Although No. 5 vein is similar to the other veins inasmuch as it generally consists of abundant quartz with patchy sulphides,

it differs in that it contains three narrow, well-defined lenses of nearly solid pyrite. These lenses are found on Nos. 8, 9 and 10 levels, but they are absent as well-defined lenses on the Snowflake as well as on the Nos. 3 and 5 levels. On the Snowflake level a considerable amount of galena was discovered, particularly in the cross-cut 90 feet back from the face at the south-east end of the drift on No. 5 vein.

No. 5A vein lies in the foot-wall from No. 5; measured across the dip it is 25 feet below that vein. It has been found in the Snowflake level and in Nos. 3, 5, 8 and 9 levels. On the Snowflake level it ranges from 2 to 4 feet 4 inches in width, at No. 3 level the short section exposed is 4 feet wide. On No. 5 level it ranges from 3 to 5 feet in width, on No. 8 level the short section cut is 1 foot wide and on No. 9 level the vein ranges from 1 foot to 1 foot 6 inches wide. On Nos. 3, 5 and 8 levels this vein is similar to the other veins in consisting of abundant, ribboned quartz with patchy sulphides, but on No. 9 level it contains a foot-wall lens of crushed pyrite. This lens (Fig. 6) is approximately 45 feet long and ranges from 1 inch to 10 inches in width. It contains a few short sections of ribbon-scheelite. It may be mentioned that on the Snowflake level a few pockets of stannite and pyrite up to 2 feet in diameter were found, particularly in the Snowflake raise. Scheelite occurs in the Snowflake level to the same extent that it does on the other levels, except for concentration in pyrite lenses on levels 8, 9 and 10.

No. 6 vein is found on Nos. 8 and 10 levels; measured across the dip it is 110 feet below No. 5 vein. On No. 8 level the short section cut is 15 feet wide. On No. 10 level it is extremely variable in width ranging from a maximum of 18 feet on the south-east to a few disconnected stringers of quartz along an intra-vein fault to the north-west (Fig. 6). The vein consists chiefly of ribboned quartz, with patchy sulphides and traces of scheelite.

Scheelite-bearing Pyrite Lenses.

Assayable amounts of scheelite occur mainly in the pyrite lenses that lie within the quartz veins. Elsewhere in the veins exposed in development the amount of scheelite is so small and so erratic in distribution that it can be considered of mineralogical interest only. Scheelite-bearing pyrite lenses occur in Nos. 5 vein on Nos. 8, 9 and 10 levels and in No. 5A on No. 9 level. They range from 1 inch to 18 inches thick, in general averaging about 6 inches, and

from 25 feet to approximately 350 feet in length. Because of extensive intra-vein faulting the continuity of these lenses on the dip of the vein may be obscure and their correlation one with the other is practically impossible in the absence of connecting winzes and raises. Intra-vein faulting, combined with the originally disseminated nature of the mineralization, has further increased their erratic distribution in the plane of the parent quartz vein. The vertical extent of these lenses in the plane of veins is indicated in only one place, namely in the "Mill" raise above level 8. Here abundant sulphide extends more or less continuously to a point 120 feet up the raise from level 8. However, down the dip below level No. 8 in raise A, sulphide lenses are absent from the vein. Although definite data concerning the extent of this mineralization on the dip of the vein are not available, the sections as cut by the drifts indicate that it is probably less than the slope distance between the levels Nos. 8, to 9, i.e., less than 190 feet. In view of the relatively small size and number of the pyrite lenses so far found in the extensive drifting done on this vein, it is not to be expected that any increase will be found with further drifting. More exploration up and down the dip of the vein would delimit those lenses already found and encounter any smaller lenses that may lie between the levels.

Estimates of Amount of Scheelite in the Pyrite Lenses.

Because of (1) the irregular shape and erratic distribution of the scheelite-bearing pyrite lenses and (2) the erratic distribution of scheelite within those lenses, it is well-nigh impossible to make a reliable estimate of either grade of mineralized material or amount of tungstic oxide (WO_3) that could be reasonably expected. Despite this, however, the writer has attempted to estimate the amount of scheelite present in the drift sections. A portable ultra-violet light was used to outline the scheelite streaks and lenses in the drift-backs by fluorescence. The data obtained were checked by taking a number of samples across the full widths of the lenses at different places where widths of scheelite varied. The summarized results of this work are given in the following paragraphs.

The longest drift-section of scheelite-bearing material occurs on level No. 9, both east and west of raise A. The easterly section begins at a point 10 feet east of the raise and extends to a point 110 feet east where the lens is cut off by the main fault. The extent up and down the dip of the vein is unknown. Comparable sections do not occur

either above in levels No. 8 or below in No. 10. Scheelite-bearing pyrite is found in the "Mill" raise for a dip-length of approximately 25 feet, but no similarly mineralized lenses occur in raise A below No. 9 level. It is probable, therefore, that the dip-length of this lens would be less than 50 feet. Based on the above method the calculated amount of scheelite in this 100-foot section is 200 lbs. of tungstic oxide (WO_3) per foot of depth for a sulphide width of 6 inches.

The westerly section on level 9 extends from a point 40 feet west of raise A to a point 225 feet west, a distance of 185 feet. The extent up and down the dip of this section is unknown. Inasmuch as it does not appear above or below on No. 8 or No. 10 levels, its extent on the dip is less than 195 feet; the slope distance on the vein between Nos. 8 and 9 levels. No information is available concerning the direction or amount of rake for any of the pyrite lenses. The dip-length is probably less than 50 feet. Based on the above described procedure, the writer has calculated that the 185-foot drift-section of this westerly lens might contain 176 pounds of tungstic oxide (WO_3) per foot of depth over a 6-inch average width of pyrite lens.

On level No. 8 a drift-section of the vein beginning at a point 150 feet east of raise A and extending to a point 250 feet east of the raise, a total distance of 100 feet, contains several disconnected short ribbons and one large kidney of scheelite. The kidney as exposed at the time of the writer's examination, measured 2 1/2 feet in length by 4 inches in width and consisted of massive scheelite cut by a few stringers of quartz; the scheelite amounts to approximately 90 per cent. of the mass, the veinlet quartz accounting for the rest. Applying the same reasoning used for the west lens on No. 9 level, the extent of the scheelite-bearing pyrite lens on the dip of the vein is probably less than 50 feet. The various sections of scheelite seen in this 100-foot drift length, when averaged over the full length, may yield 48 pounds of tungstic oxide (WO_3) per foot of depth across an average width of 6 inches of pyrite lens.

A lens of scheelite-bearing pyrite on No. 10 level in No. 5 vein at its north-western end exposes a length of 17 feet, and an average width 7 1/2 inches. The minimum value for the dip-length of this lens is 20 feet and the maximum is unknown, though probably less than 50 feet. The samples taken indicate that 400 pounds of tungstic oxide (WO_3) per

foot of depth over 7 1/2 inches may be expected for the 17-foot length.

Suggested Development.

The writer submits the following suggestions for further work, should any be contemplated on the property, namely that:

(1) Efforts should be directed towards the exploration of only the scheelite-bearing pyrite lenses. Although it is doubtful if these will carry any large amounts of economically mineable ore, still a small tonnage of scheelite could be obtained from them.

(2) The pyrite lens in the west end of No. 5 vein on No. 10 level be drifted on to the north-west.

(3) The cross-cut that extends north-easterly on No. 9 level from a point 220 feet east of raise A, be extended farther north-easterly to intersect the south-easterly extension of No. 5 vein across the main fault. To pick up a point corresponding to one on the north side of the fault at this level it would be necessary to go down the dip of the fault for 50 feet on the south side of the fault.

(4) In general, raising and sinking could be done from the drift-sections of the scheelite-bearing pyrite lenses to their extremities.

NELSON AREA

Scheelite has been reported as occurring in small amounts in many of the gold properties in this area. The largest quantities have been reported from the Venango, west of Nelson and from the Euphrates south of Nelson. It is understood that earlier in the year (1940) the companies operating these properties contemplated saving the scheelite when milling their gold ores. To date there has been no production. Tungsten minerals, chiefly of mineralogical interest only, have also been reported from several other properties in the area, as follows:

Buff-colored scheelite has been found occasionally in the quartz veins on the Venango, latitude north 49 degrees 23 minutes, longitude west 117 degrees 24 minutes, on the west side of Eagle Creek near Blewett about 5 miles west of

Nelson. It occurs in scattered grains and in nodules of massive mineral. One specimen seen by the writer measured approximately 5 inches in maximum dimension.

Scheelite in the Poorman mine, approximately latitude north 49 degrees 29 minutes, longitude west 117 degrees 24 minutes, across Eagle Creek from the Venango, has been mentioned by LeRoy (VII, 1911, p. 147) and is described as being of rare occurrence in the veins on the property. Scheelite has also been reported (H. C. Hughes, personal communication) from the adjoining Royal Canadian and Nevada groups.

At the Euphrates mine, latitude north 49 degrees 22 minutes, and longitude west 117 degrees 14 minutes, now being worked by the Gold-Silver-Tungsten Mining and Milling Company, Ed Terzien, President, at Hall Siding, about 10 miles south of Nelson, scheelite occurs in small amounts in the gold-quartz veins. It is understood that during 1940 plans were made for the installation of flotation cells in the company's mill to recover this mineral as a by-product from the milling of the gold ores. However, the writer is not aware of any scheelite production to date from this property.

At the old Porto Rico, approximately latitude north 49 degrees 19 minutes, longitude west 117 degrees 20 minutes, approximately 5 miles northwesterly from Ymir, tungstite was reported to Walker (VI, 1909, p. 38) to have been found on the concentrating tables. It has also been reported (H.C. Hughes, personal communication) from the Spotted Horse approximately 1 mile northeasterly from the Porto Rico.

From near Ymir, latitude north 49 degrees 17 minutes, longitude west 117 degrees 12 minutes, scheelite has been reported from the Old Timer mine.

In the Kootenay Belle mine, latitude north 49 degrees 9 minutes, longitude 117 degrees 7 minutes, on Sheep Creek, Brock (VII, 1908, p. 19) described wolframite and scheelite as occurring in bunches or kidneys, occasionally in masses weighing about 30 lbs., in the quartz. It was reported to Walker, (VI, 1909, p. 38) that during the earlier operations at the Queen mine, near the Kootenay Belle, tungstite was seen on the Wilfley table when operating on oxidized ore. Mining operations have been carried on fairly continuously from that time to this, but no increase has been found in the amount of scheelite. Tungsten has been recovered from tables in the old Reno mill, latitude north 43 degrees 10 minutes, longitude west 117 degrees 8 minutes.

North-westerly from Nelson the occurrence of scheelite on the Meteor, latitude north 49 degrees 48 minutes, longitude 117 degrees 22 minutes near Slocan City, has been described by Cairnes (VII, 1935, p. 180) as follows:

> "Scheelite was also discovered in the Meteor vein. It is stated to have formed a mass of about 500 pounds on No. 2 level where it occurred as a wedge-shaped body about 12 feet long and 4 inches thick at the base. A small kidney of scheelite, amounting to about 25 pounds, was also found on No. 4 level."

North-easterly from Nelson, scheelite has been reported (H. C. Hughes, personal communication) from the Alpine mine, approximately latitude north 49 degrees 41 minutes longitude west 117 degrees 14 minutes, near the head of Sitkum Creek and from the Scranton, latitude north 49 degrees 48 minutes longitude west 117 degrees 6 feet, near the head of Woodbury Creek.

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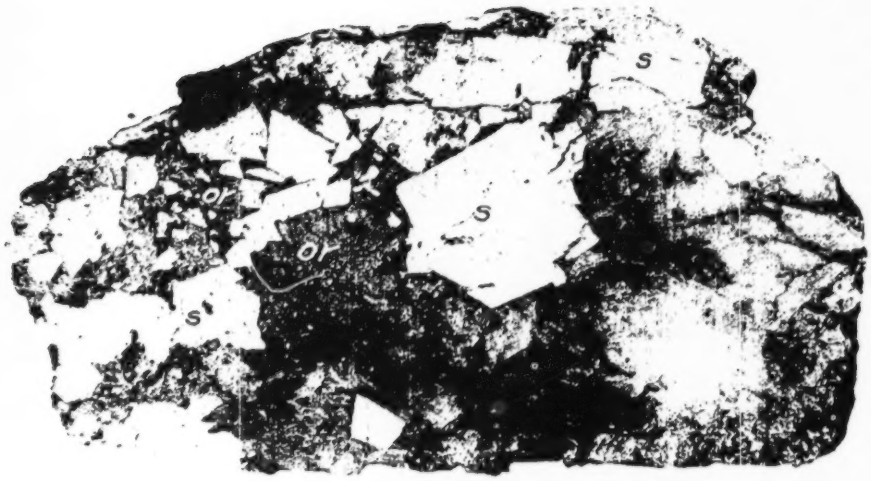

Plate I A Red Rose. Scheelite (s) in a gangue of quartz (qtz) and orthoclase feldspar (or). Twice natural size.

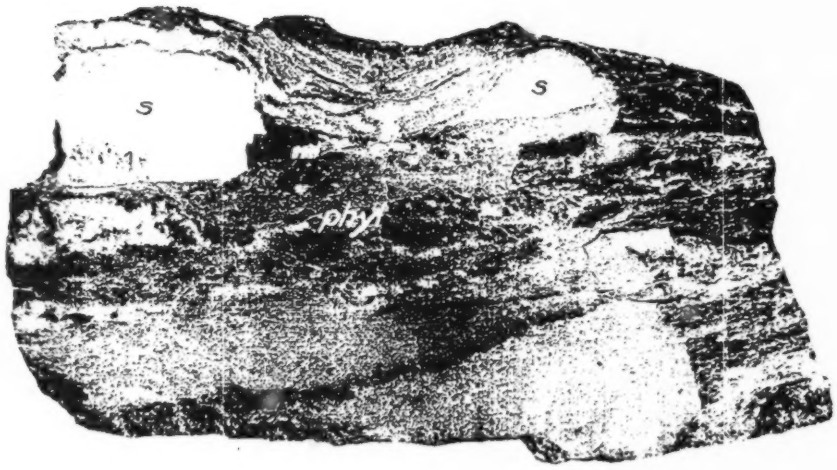

Plate I B Columbia Tungstens Company, Limited (Hard-scrabble). Nodules of solid scheelite (s) in phyllite (phyl). Natural size.

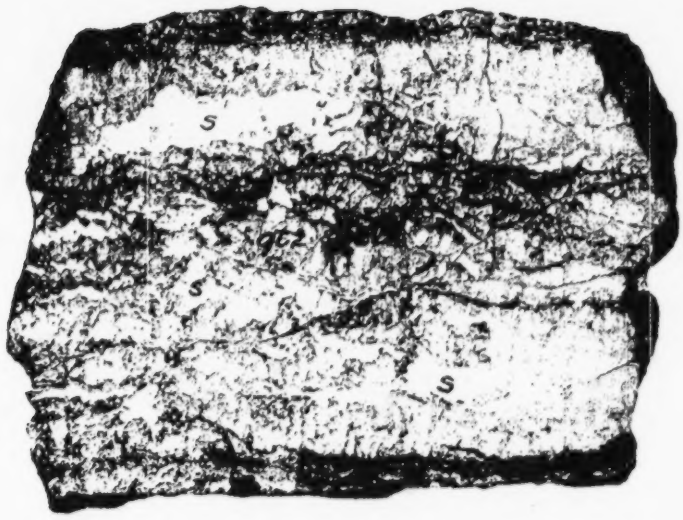

Plate II A Columbia Tungstens Company, Limited (Hardscrabble
Disconnected patches and thin irregular streaks of
scheelite (s) in quartz-carbonate gangue
(qtz & cb). Natural size.

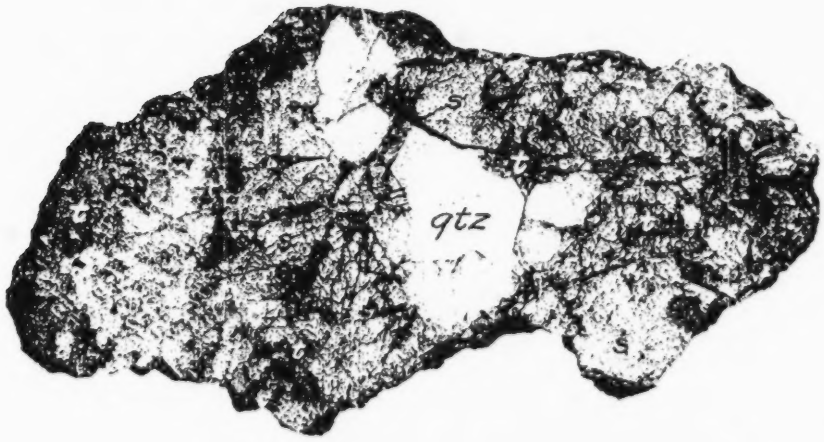

Plate II B Taylor property. Vein-matter showing scheelite
(s) being replaced by tungstite (t). Quartz (qtz).
Twice natural size.

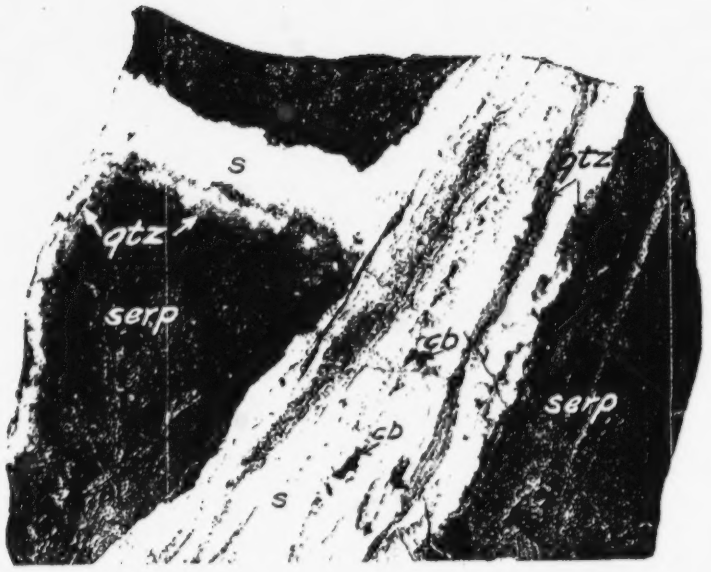

Plate III A Phillips' Tungsten. Vein of scheelite (s) containing chalcedonic quartz (qtz) and ankeritic carbonate (cb) in carbonatized serpentine (serp). Natural size.

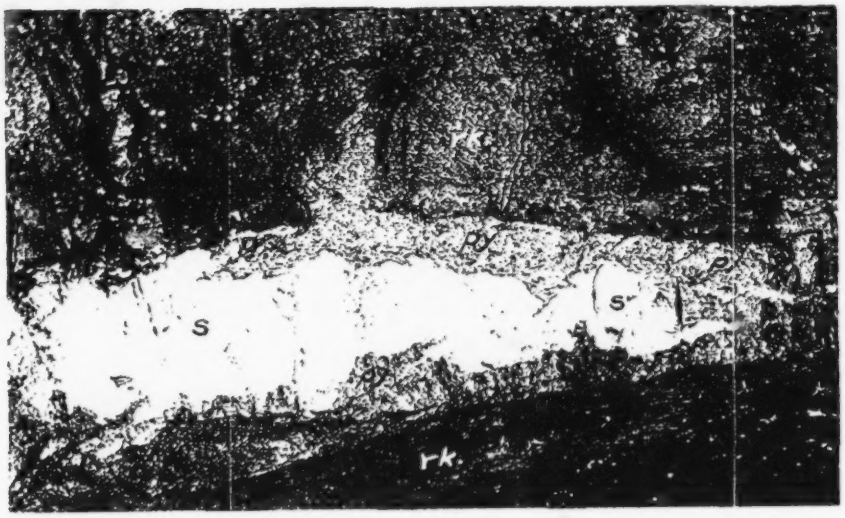

Plate III B Regal Silver. Relatively pure scheelite (s) in a pyrite lens (py) of No. 5 vein, as seen in the floor of No. 8 adit at a point 240 feet west of Raise A. Wall rock (rk) is slaty argillite. One-seventh natural size.

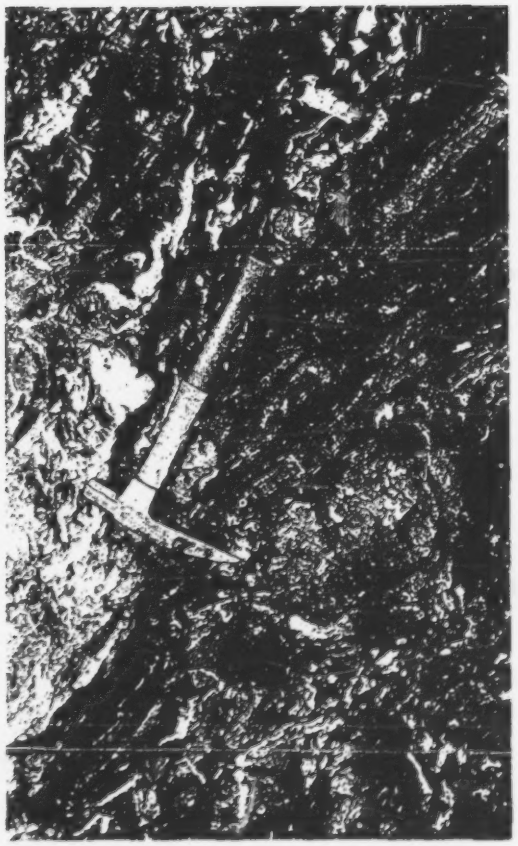

Plate IV A Regal Silver. Crushed graphitic slate and lenticular quartz in main fault-zone as seen in No. 8 adit.

Plate IV B Regal Silver. Ribbon texture as seen in quartz vein in back of Raise B, No. 10 adit. Vein 4 feet wide.

Plate V A Regal Silver. Fractured scheelite (s) with quartz (qtz) and pyrite (py). The distribution of the scheelite is approximately parallel to wall of enclosing pyrite lens. Natural size.

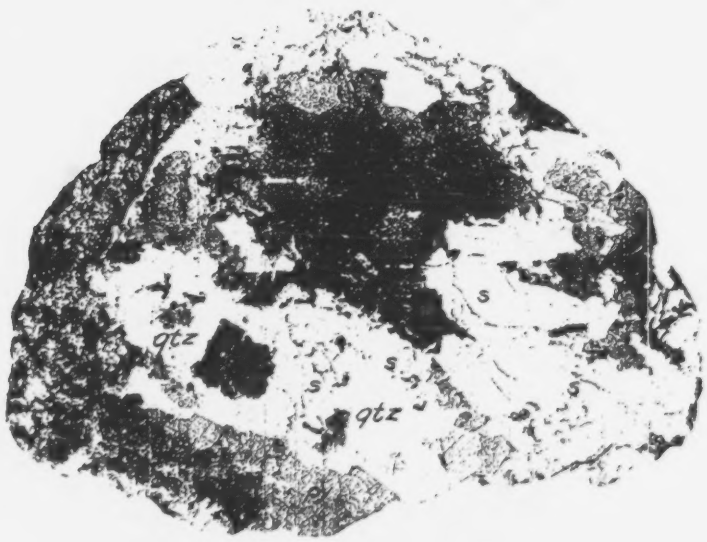

Plate V B Regal Silver. Disconnected patches of scheelite (s) and quartz (qtz) in pyrite (py) of a pyrite lens. Natural size.